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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 193

Contribution from the Office of Experiment Stations
A. C. TRUE, Director

Washington, D. C. PROFESSIONAL PAPER April 30, 1915

THE DRAINAGE OF JEFFERSON COUNTY, TEXAS

By

H. A. KIPP, A. G. HALL, and S. W. FRESCOLN
Drainage Engineers

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

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INTRODUCTION.

The drainage of Jefferson County, like the drainage of all other counties along the Texas Gulf coast, has been generally recognized in recent years as one of the most important steps in the agricultural development and settlement of this comparatively new country. Several attempts have been made to organize drainage districts within the county under the Texas drainage law and to start actual construction of some drainage canals to relieve the land of the surplus water, but up to the present time construction has been carried out in only one district. Outside of that district few canals have been constructed, and the conditions throughout the county generally have not been improved.

In January, 1912, the Chamber of Commerce of Beaumont requested the assistance of Drainage Investigations, Office of Experiment Stations, United States Department of Agriculture, in making drainage plans and estimates for Jefferson County. On February 15 the county commissioners' court adopted resolutions agreeing that if Drainage Investigations would make the necessary survey and prepare a drainage plan the county would bear one-half the cost. The survey and

Note.—This report is intended especially for engineers, drainage district officials, and present and prospective owners of land near the Gulf of Mexico, particularly in Texas and Louisiana. The run-off formula and discussion will interest all engineers concerned with land drainage.

plan were roughly estimated to cost $15,000. Following a preliminary investigation and report, the cooperation offered by the county commissioners was accepted and the survey was authorized. Headquarters for the survey were established at Beaumont; field work was begun April 8 and completed December 1, 1912.

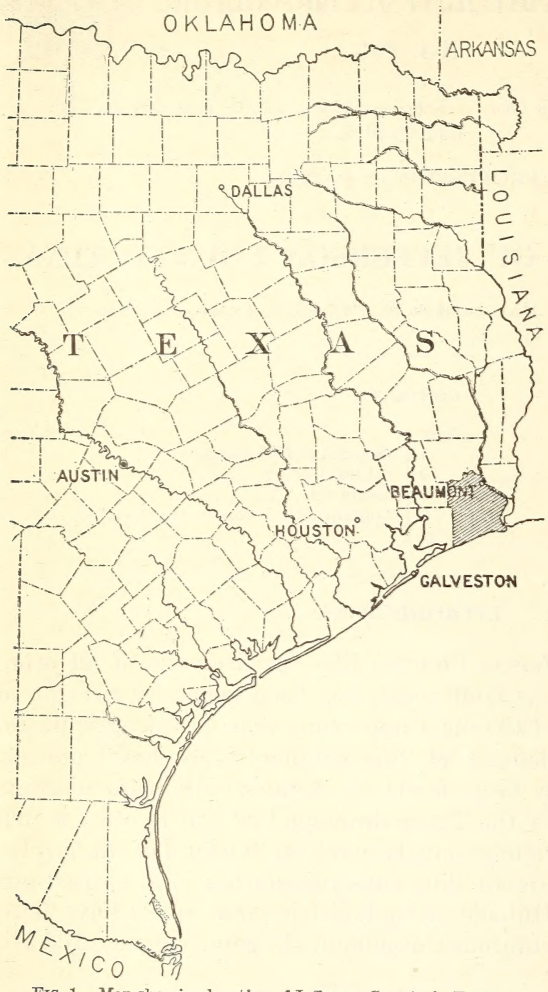

FIG. 1.—Map showing location of Jefferson County in Texas.

GENERAL DESCRIPTION OF JEFFERSON COUNTY.

Jefferson County is wholly within the Coastal Plain of southeast Texas, reaching from the Gulf of Mexico on the south to Pine Island Bayou on the north and separated from Louisiana by Sabine Lake and Sabine Pass. (See fig. 1.) The area is approximately 956 square miles, or 612,000 acres, and the population about 40,000. The principal cities of the county are Beaumont and Port Arthur. The proposed Intercoastal Canal to connect the Neches River and the Sabine-Neches Canal with Galveston Bay will traverse the southern part of the county, and Taylors Bayou is used extensively for transportation by the farmers in the central part. About 100 miles of shell highways and about 500 miles of graded earth roads traverse practically all parts of the county except the great salt marshes bordering on the Gulf.

The principal agricultural products of the county are rice and garden truck, but quantities of cotton, corn, and fruits are raised. In the northern half of the county is a very extensive system of canals

for rice irrigation, about 500 miles of mains and laterals being now in use. The live-stock industry is extensive, particularly in the southern part where many thousands of acres are given over to grazing. The turpentine industry along Pine Island Bayou is a source of considerable activity and profit. The country between Beaumont and Port Arthur is studded with huge oil tanks and oil pumping stations.

TOPOGRAPHY.

The surface of Jefferson County is typical of the Coastal Plain, being generally flat and level with few physical features especially marked. The land was built from deposits brought from higher elevations by the streams, and later exposed when the waters of the Gulf receded. Figure 2 (in pocket at end of bulletin) shows the principal water courses, the watershed lines, and the areas drained by the streams.

The highest elevation in the county is 46 feet above sea level, in the northwest part near Nome. From the northern part of the county the ground slopes gradually southward to a great level tract of salt marsh scarcely 1 foot above sea level bordering the Gulf, Sabine Lake, and the lower reaches of the Neches River. To the eye the whole county seems perfectly level, but instrumental surveys show that the surface, excepting the low flat marshes, is undulating and has a considerable slope. This fact is in a measure shown by the locations of the main irrigation canals, which usually follow the higher contours. The only marked slopes in the county, besides the bluff bordering the Neches River marsh and the sloping banks of Pine Island Bayou, are Spindletop oil field south of Beaumont and Big Hill 7 miles south of Hamshire. Spindletop is 10 to 12 feet higher than the ground one-half mile west of the center of the oil field, and Big Hill has an elevation of about 20 feet above the surrounding country. There are a few places along Taylors Bayou near La Belle where the banks are high.

The entire northwestern portion of the county is peculiarly devoid of well-defined streams or drainage channels. Water stands on the ground for weeks at a time after every rain, and sometimes the land remains under water throughout an entire season. Under present conditions evaporation is a greater agent of natural drainage in this section than percolation or flow to any natural outlet. The west-central part of the county is also lacking in large natural channels which would aid drainage, and there are only a very few small streams like Spindletop Gully and the upper end of Big Hill Bayou which carry the overflow waters down to the salt marsh adjacent to the coast. Several large bodies of level inland or fresh-water marshes occur in various parts of the county where water stands the greater part of the year.

A natural sand levee 4 to 6 feet high extends practically the full length of the Gulf shore line. This levee was formed by wind and wave action and protects the salt marsh adjacent to the Gulf from ordinary storm tides. Owing to a gap in the levee, however, protection is not afforded against the extreme storm tides which occur at irregular intervals of one to ten years.

WATERCOURSES.

The Neches River is a winding stream 20 to 40 feet deep and ranging from 400 to 800 feet wide. The banks are generally low and flat, being scarcely 1 foot above the ordinary water level. Marshes 1 to 2 miles wide separate the high land from the river except at Colliers Ferry, Beaumont, the Port Arthur Rice & Irrigation Co.'s pumping plant, and Port Neches. The total length of bluff line fronting directly on the river is about 3 miles. The river bluff, which extends from the Neches Canal Co.'s pumping plant at Voth to the mouth of the river, is higher than the land back from the stream, and practically all drainage is away from the river. A few small gullies break the bluff line and provide drainage for adjacent ground, but very little drainage from Jefferson County enters the Neches except what comes through Pine Island Bayou. A strip of land bordering that bayou along its entire length in the county and averaging about 3 miles wide slopes rather abruptly toward the stream and is drained by that route; the remainder of the county, except a very small portion in the southwestern corner and the great salt marsh bordering on the Gulf, is drained into Sabine Lake by way of Taylors Bayou and its tributaries.

Taylors Bayou is the principal water course within the county, rising in a large fresh-water marsh north of Hamshire and emptying into Sabine Lake. It is very crooked, and is 10 to 15 feet deep and 200 to 400 feet wide along the lower portion. Tide water extends up the bayou to a point near the center of the county. Upstream from that point the banks of the bayou are covered with timber and heavy underbrush. The channel as a rule is badly clogged with logs, driftwood, and débris, which together with the bends in the stream, greatly impede the natural drainage, although improvements in drainage district No. 3 have greatly relieved the upper reaches. The principal tributaries of Taylors Bayou are the North Fork, Hillebrant Bayou, Mayhaw Bayou, and Rodair Bayou. The North Fork is similar in all respects to the upper end of the main channel. Hillebrant Bayou is a tortuous stream flowing through a strip of heavily timbered land. It is badly obstructed by fallen timber, driftwood and brush growing in the channel, except in the lower reaches where the channel is wide, deep, and open. The western part of the city of Beaumont suffers greatly from the frequent overflows. The principal tributary of

Hillebrant Bayou is Bayou Din, similar in all respects to the upper end of Hillebrant Bayou. Above the Gulf & Interstate Railway crossing the channel is not well defined, and below the railroad the stream banks are overgrown with timber and brush. The two other important tributaries, Pivitot Bayou and Willow Marsh, provide much better drainage to the adjacent lands than does Bayou Din. They are less winding, and they flow through open country, therefore the channels are less obstructed by logs and driftwood than are the streams flowing through the woods.

The great salt marsh is traversed by Salt Bayou which heads in Star Lake about midway between Sabine Pass and the west county line, leads northeasterly through a number of shallow lakes and parallel to the Gulf shore, then turns north into Taylors Bayou near West Port Arthur. It is the outlet for Kieth Lakes, Salt Lake, Knights Lake, Fence Lake, and some others. Big Hill Bayou is a much smaller watercourse draining an area between Salt Bayou and Taylors Bayou. Mud Bayou, in the extreme southwest corner of the county, flows through Chambers County into Galveston Bay and is the only stream not having its outlet in Jefferson County. Alligator Bayou drains a considerable area of marsh and of higher lands west and north of Port Arthur. In several places it spreads over the marshes without any defined channel, but in many respects is similar to Salt Bayou. These bodies of water are at tide level and are subject to all the tidal changes of the Gulf, the extent to which they are affected depending upon the height and duration of the tides. They are of little value as drainage channels because they have practically no fall and are very shallow and crooked.

CLIMATE.

The region is characterized by long warm summers and short mild winters. Records of the United States Weather Bureau indicate that the summer temperatures seldom exceed 100° F., and as a rule the heat is tempered by cool breezes from the Gulf, for the prevailing winds are southerly. The average annual temperature at Beaumont is about 68°, the average monthly ranging from about 52° in February to 82° in July. Extreme variations from these averages sometimes occur, heavy killing frosts in winter and very hot weather for short periods in summer being not at all uncommon. In winter especially, sudden drops of temperature are caused by cold north winds commonly known as "northers"; the cold spells seldom last more than a few days at a time, however.

The mean annual precipitation at Beaumont during the past 20 years was 46.3 inches, and at Houston 48 inches. For ordinary crops the rainfall is sufficient in amount and evenly enough distributed, but rice culture makes irrigation necessary.

SOILS.

In connection with the drainage survey a number of soil borings were made in all parts of Jefferson County to depths of 10 to 15 feet, to ascertain whether any unusual difficulties would be encountered in the construction of ditches and levees or in draining the land by tiling. Several distinct types of soils were found, the predominating surface soils being fine sandy loams, loams, clay loams, silt deposits, and muck, all underlain by a deep stratum of clay. Limited areas of fine sand were also found at the surface in certain parts of the county.

The most common type of surface soil is the fine sandy loam, averaging 12 to 14 inches deep; this was found upon practically all the higher land which may be drained by gravity. The loam soils are mostly found in the great flat areas or fresh-water marshes in the interior of the county. The marshes bordering on the Neches River are composed entirely of alluvial soil, and the open marshes south of Beaumont are largely muck with a high percentage of silt. Parts of these marshes are so soft it is nearly impossible to walk across them. The great marsh in the southern part of the county is composed principally of muck formed by decaying marsh grass, underlain by silt. Practically every boring encountered clay between the 2-foot and 10-foot depths; below 10 feet the clays contained much sand, and some pockets of quicksand were found at 10 to 13 feet.

So far as the construction of drainage works is concerned, no particularly unfavorable soil conditions were found on the upland portion of the county. The underlying clays of that region are quite impervious and prevent the downward percolation of water, and it is this fact that makes the level prairies so valuable for growing rice. However, where any other crops are grown it will be found advantageous to lay tile to remove the surplus water from the soil. Tiling has not been tried to any extent in Jefferson County, principally because rice is the principal crop and because there are at present no outlets for underdrains, but there is no doubt that this kind of drainage will work successfully in this soil. The marsh soils may cause considerable trouble during construction if caution is not exercised in handling the soft materials. The removal of surplus water from the ground will tend to solidify the marsh soil, and cultivation will assist in making it firm. Sugar cane, rice, corn, forage, and truck have been raised in Louisiana on reclaimed marsh lands that appear to be similar to the marshes of Jefferson County, Tex.

NATURAL VEGETATION.

The natural vegetation on the great level prairies is ordinarily prairie grass and sedge. The salt marshes support a heavy growth of salt or wire grass, and in some places, particularly along the bayous

and low spots, dense growths of rushes and reeds are found. Both the prairies and the marshes are used for grazing purposes. Approximately nine-tenths of the county is in open prairie or marsh, the remainder being covered with the native growth of timber and underbrush. Lawhorns Woods, located north and west of Fannett, and Pine Island Bayou Woods are the largest timber areas, but several other patches are found along the upper reaches of Taylors Bayou, on Hillebrant Bayou and Bayou Din, and along the Neches River bluff. Pine is the predominating tree, but water oak, live oak, and post oak are also plentiful. The undergrowth is thick and consists of palmetto and other semitropical vegetation, green briars, and blackberry bushes.

PRESENT DRAINAGE SITUATION.

As a whole, the county has very poor natural drainage, as has been indicated. In only a few favored spots is the ground well drained, and practically every farm should have artificial drainage either by open ditches or by tile. Farmers in all parts of the county have suffered severe losses, and the rice farmers are particularly in need of some means of draining their fields during planting and harvesting seasons. Practically the entire southern half of the county is very wet and marshy at all times, and until some system of thorough drainage is installed the land can not be cultivated at all.

DRAINAGE DISTRICTS ORGANIZED.

Drainage district No. 3, comprising about 47,000 acres south of Hamshire, has had surveys and plans made, and construction has been completed. Two other attempts to organize drainage districts have been made, but owing to lack of cooperation among the landowners and to the inadequacy of the law the organizations have not been perfected and no construction work has been done. Some years ago several drainage ditches were constructed south of China, but they have not been well maintained and will need to be reconstructed before they will fulfill the purpose for which they were intended. They have no outlets and are neither large enough nor deep enough.

THE SURVEY.

Carefully checked base levels were first run on all the railroads from Beaumont to the boundaries of the county. Bench marks were established at intervals of 1 mile or less on railroad mileposts or other convenient objects. All elevations were referred to sea-level datum as established by War Department engineers. Lines of levels were run across the county at intervals of 1 mile or less, approximately east and west or north and south, generally with the slope of the ground. Roads and fences were often followed for convenience. Tie lines were run perpendicularly to the cross lines in order

to determine additional elevations and to check the work. Very little time was given to locating property corners, and as most of the land is divided into irregular tracts according to original surveys, the cross levels were all located with respect to mileposts or other objects of known location along the railroads. The south end of the county is subdivided into square miles which are numbered consecutively, but a great many of the corners are now obscured and the level lines were located only approximately. All the streams were meandered with compass and stadia, and levels were carried on many of the meanders. A sufficient number of channel cross-sections were taken to determine the sizes and capacities of the streams. For determining the area drained into Jefferson County from the west, lines of levels were projected west from the county line at intervals of 2 miles and were carried beyond the divide between the Trinity and Neches Rivers. Numerous bench marks were established in all parts of the county, the locations, descriptions, and elevations of which may be obtained upon request to the Chief of Drainage Investigations, United States Department of Agriculture.

A tract of about 70 square miles lying east of the Texas & New Orleans Railroad (Sabine branch) was omitted from this survey because the owners furnished a contour map of the tract, which was adopted as correct after being checked by several lines of cross levels. A number of land maps furnished by the county surveyor and right-of-way maps supplied by the railroads were of great assistance in making the survey.

The map of Jefferson County (fig. 3, in pocket at end of bulletin) was drawn to a scale of 3,000 feet to the inch, the outline being compiled from a War Department map of the Neches River, a Coast and Geodetic Survey map of the Gulf shore, and the county surveyor's maps of the west county boundary, and a right-of-way map of the Southern Pacific Railroad. Upon this skeleton map were plotted all the data obtained from the survey and from maps furnished by the county surveyor, the railroads, and several irrigation and land companies. The map shows also the complete system of drainage improvements proposed for the county. It should be noted, however, that drainage district No. 3 was organized and had begun construction before the project was undertaken, and the plans shown for that district are not the work of Drainage Investigations.

THE DRAINAGE PROBLEM.

As in most other counties of Texas bordering on the Gulf, the great areas of undrained and unimproved lands in Jefferson County present several problems in their reclamation. The low-lying tracts of salt marsh adjacent to the Gulf which are subject to over-

flow due to storm tides, the river marshes which are periodically submerged when the Neches overflows, the higher lands in the north half of the county which are frequently inundated by excessive rainstorms, and the necessity of coordinating drainage improvements with existing systems of irrigation canals, make the designing of a proper drainage plan for this county unusually difficult.

The first consideration in planning the drainage of a large area is to divide it into such districts that each can be drained just as soon as the landowners are ready to undertake the improvements, without regard to progress in adjoining units. Natural watershed lines ordinarily determine the boundaries of districts to be drained by gravity, while pumping units are usually planned to secure the greatest economy in cost of administration, construction, and operation. The principal faults with the gravity districts heretofore planned have been that they were established without due regard to the natural features that should determine the drainage units, and that ditches were designed without properly considering the areas that they would need to drain.

In Jefferson County the division into practicable drainage districts is complicated by the fact that Taylors Bayou is the natural outlet for 597 square miles, practically two-thirds of the county. Tide water extends up this stream and some of its branches for 25 miles from Sabine Lake. Because the ground is so level, it is impossible to secure a greater slope for the water surface below the North Fork than 0.15 foot per mile at mean tide elevation. To provide capacity for the water that will come to it, this bayou must be considerably enlarged, and to spread the cost of this work equitably over all the land drained by the watercourse is no mean undertaking.

The most practicable drainage plan could not be determined without having considered both irrigation and water transportation. This is particularly true of the latter, and in designing the drainage system herein recommended due consideration has been given to the proposed Intercoastal Canal and to the improvement of several of the larger streams for transportation purposes. The plan recommended is believed to be such that the lands may be improved in logical sequence and without unduly burdening the property owners who must pay for the reclamation, and at the same time such as will result in the most effective and economical improvements. The following pages show in detail how the various factors which enter into the plan for drainage and accessory results are provided for. Hydraulic problems and methods of construction affecting the design of the drainage works are discussed, and estimates of cost are presented for each drainage unit.

RUN-OFF.

Practically all of the water which falls upon any drainage area, except that which is returned to the air by evaporation, that which is taken up by vegetation, and that which sinks far into the earth, passes over or through the ground to the main outlet watercourse, and is termed the run-off from the area. To insure thorough drainage at all times, the ditches and the pumping machinery must be of sufficient capacity to remove the water of the heaviest rainstorm within a reasonable time. Economy, however, dictates that the design should not contemplate handling the run-off from the extremely heavy storms that occur only at intervals of several years. The exact length of time that water may stand on the ground without doing any appreciable damage to crops or without interfering materially with field operations is variable and indeterminate, but it is assumed that the surplus water should be removed from the ground surface within 24 hours.

RUN-OFF MEASUREMENTS.

Of course the best basis for determining the proper capacity of drainage channels or pumping plants is a number of measurements of the maximum flood flow following storms of the greatest severity against which it seems practicable to provide. More often than not, drainage improvements must be designed with only the most meager data of this kind, or none at all. Few opportunities for actually gaging flood run-off in this locality were presented during the survey, but the following data were obtained, which serve at least as an important check on the run-off computations discussed later.

Gagings of Taylors Bayou were made April 18, 1912, at two places near Hamshire, and the following day a gaging was made of Hillebrant Bayou at the Iron Bridge. Flood conditions prevailed then due to a storm of 3 to 4 inches on April 16, covering the watershed area, preceded by general rains that had saturated the soil. A gaging of Pine Island Bayou at the highway bridge near Voth was made May 12. Heavy rains two days previous caused the high water, but the crest of the flood occurred about 24 hours before the gaging was made; therefore the maximum run-off rate was slightly greater than that observed.

A private firm of civil engineers made gagings of Brays Bayou near Houston on December 16, 1911, during one of the wettest periods on record. The results may be used with those obtained in Jefferson County, as run-off conditions are similar. Run-off data gathered from pumping districts in southern Louisiana during several years of investigation are also available.

FACTORS AFFECTING RUN-OFF.

The amount of run-off depends upon the rate and amount of rainfall, modified by the size and form of the drainage area, the slopes of the ground, the arrangement of the watercourses, the nature of the soil, the transpiration of plants and evaporation, the natural storage reservoirs, and the drainage improvements within the watershed area. In the following discussion the rate of run-off is expressed in inches depth over the entire drainage area removed in 24 hours, or in cubic feet per second, commonly abbreviated to "second-feet." On the proper determination of the maximum rate of run-off that the drainage works should remove will depend largely the economy and efficiency of those improvements. Since the run-off is dependent upon several factors of variable values, the determination of the proper rate requires wide experience and mature judgment.

RAINFALL.

It is usual to determine first the intensity of the most severe storm against which protection should be provided. The rainfall records secured by the United States Weather Bureau in Jefferson County and the vicinity show a very uneven distribution of the precipitation, with storms of great intensity. More rainfalls and more heavy storms occur from March to September than during the rest of the year, usually; therefore overflow is the more likely to occur during the growing season. The average annual precipitation at Beaumont during the past 15 years is about 42.6 inches, at Galveston 46.3 inches, and at Lake Charles 53.9 inches.

Some of the most notable storms recorded at Beaumont during those years are as follows: October 14, 1902, 9.26 inches; November 4, 1902, 6.25 inches; and November 31, 1902, 6.87 inches. Lesser storms during and immediately following these several precipitations must have kept the ground saturated. June 25, 1905, 6.51 inches fell, preceded and followed by heavy rains, and October 14, 1906, 5.12 inches of rain occurred. During May, 1907, 19.40 inches of rain were recorded, 13.3 inches of which fell in two storms on the 23d and 30th. April 14, 1908, 5.80 inches rainfall occurred, preceded and followed by lesser storms, and during the first 10 days of July of the same year 9 inches fell. It will be noted that these excessive storms are of infrequent occurrence, but the records from all the stations show that from 1892 to 1912, between March and October each year there occurred one or more storms of 3 to 4 inches at times when the ground must have been well saturated, and that heavier storms were rather local and not general over the county.

In view of the facts stated above, it seems wise to design the drainage improvements for this county to care for the run-off from a rainfall of 4 inches in 24 hours. At very infrequent intervals the ditches

may overflow and the pumps be flooded, for short periods, but it seems economically impracticable to provide against such unusual conditions.

RUN-OFF FORMULA.

Many attempts have been made to devise a mathematical expression involving various of the factors that modify the maximum run-off rate, for use in estimating run-off when there are not actual gagings that will serve as a fairly reliable guide. A formula has been suggested by S. W. Frescoln for computing the run-off depth to be expected from any simple drainage area. It is as follows:

$$D = CM\sqrt{PF}\frac{(B+L)^{\frac{3}{2}}-(B^{\frac{3}{2}}+L^{\frac{3}{2}})}{BL}$$

in which

D = maximum rate of run-off, in inches per 24 hours, to be expected from the rainfall P.

C = a coefficient depending solely upon the physical character of the soil, and determined by experiment.

M = the ratio of total run-off to total rainfall, for the precipitation P, varying with evaporation, deep percolation, lateral seepage from the drainage channels, and duration of flood.

P = the depth of rainfall in inches in 24 hours (4 inches for Jefferson County).

F = the average slope of the ground surface of the drainage area, in feet per mile.

L = the mean length of the drainage area in miles.

B = one-half the mean width of the drainage area in miles.

For drainage areas that contain storage reservoirs, a special calculation must be made to eliminate the effect of the reservoirs. Where the main watercourse is formed by the junction of two or more large tributaries, the formula is to be applied to each tributary separately, and the proper value of the run-off depth for the entire area will be the weighted mean of the values for the parts.

APPLICATION OF THE FORMULA.

The values of L, B, and F are determined from the drainage survey, P from rainfall data as already explained, M and C by comparison with other drainage basins where gagings and other flood data have been secured.

The value of $\sqrt{F}$ is determined for each simple drainage basin by first dividing the area into units wherever there is a marked change in the surface relief, as where a flat area joins a rolling or hilly section, each unit wholly on one side of the main stream. The mean $\sqrt{F}$ is found for the course which the water will take from each corner of the unit to the outlet of the whole basin and the average of these

values is considered the $\sqrt{F}$ for that unit. The value of $\sqrt{F}$ for the whole drainage basin is the mean of the values for the separate units, each weighted according to the area of the unit. Special care is required in dividing the drainage units for a basin consisting of lands rising quickly from a main channel of small slope, that the large slope of the lands near the outlet may not have undue weight in the final value of $\sqrt{F}$. For land as level as some of the pumping districts the slopes of the water surfaces in the ditches must be used for computing $\sqrt{F}$.

The value of M for any drainage area is affected by several factors, as noted on page 12. This ratio has been determined by stream measurements for certain areas outside Jefferson County, and the values for the various districts in this county were calculated by comparison with known data, estimating the combined effect of evaporation, seepage, and percolation as 0.1 inch per day and making due allowance for other varying conditions.

The value of C, since it can not be measured directly, is to be computed by solving the formula for conditions where all the other factors, including D and M, are known. A sufficient number of repetitions of this computation covering several drainage areas having similar soil characteristics should determine reliable values for C if the various modifying factors are correctly involved in the formula. Quite a number of such computations have been made, which have given results quite uniform for each type of soil considered.

The value for C, determined in the manner just indicated, for clay soil, such as most of that in Jefferson County, is approximately 1.50. Using 0.87 for M, found in the manner described, for Taylors Bayou at the points where the run-off measurements were made, C is computed as 1.49. For the gaging of Hillebrant Bayou 0.66 was found for M and 1.56 for C. This difference in these two values for M is due principally to the great difference in the size of the areas drained. The value of C computed from the gaging of Brays Bayou near Houston agreed well with the values given above, so 1.50 was used for C in the computations for the Jefferson County ditches. The maximum rate of run-off in 24 hours of course would not exceed the rainfall.

PROPOSED PLAN OF DRAINAGE.

The general plan proposed for the drainage of that part of Jefferson County which can be wholly or partially drained by gravity consists in (1) dividing that part into its natural drainage units; (2) straightening and enlarging all the present watercourses that will become the main outlets or arteries for a complete drainage system; and (3) constructing systems of parallel ditches, spaced one-half mile apart and

running generally with the greatest slope of the land, reaching to the boundaries of each district.

The plan proposed for the remainder of the county consists in (1) dividing it into convenient pumping districts; (2) straightening and deepening certain watercourses and constructing the proposed Intercoastal Canal, all of which will serve as outlets for the pump discharges; (3) building levees to prevent the overflow of those districts by tides, backwater from the river, or run-off from higher lands; (4) constructing systems of parallel ditches spaced 1 mile apart and reaching to all parts of each district; and (5) erecting pumping plants to lift the water from such inclosures over the protection levees. Spacing the lateral ditches 1 mile apart in each of the pumping districts will give ample relief for the present needs of the county, but it must be borne in mind that when those areas are put under cultivation additional ditches must be constructed. The number of lateral ditches should then be doubled, making them one-half mile apart. They should be fed by small collecting ditches or field laterals perpendicular to the larger ditches. It may be found practicable to use tile drains instead of open field ditches. In many newly reclaimed tracts in Louisiana these field laterals are made 4 feet deep, 4 feet wide at the top, 1½ feet wide at the bottom, and are spaced 165 or 330 feet apart to divide the land into 10-acre or 20-acre plats between the larger ditches. Pine Island Bayou and Taylors Bayou should be improved as outlined on later pages. The work on each stream will benefit several units, and the cost should be apportioned according to the benefits to be received. The entire south end of Hardin County and a large area in Liberty County will receive direct benefit from the improvement of Pine Island Bayou, but since the present State drainage law makes no provision for cooperation between counties in doing such work it is proposed that no more work be done on that watercourse than will be necessary to meet the needs of Jefferson County. All the drainage units drained into Taylors Bayou will be benefited by the improvement of that stream below the mouth of Mayhaw Bayou near the limit of tidewater.

DRAINAGE UNITS.

GRAVITY DISTRICTS.

The gravity drainage districts are Nos. 1, 2, 4, 5, 10, 11, 12, 15, 20, 25, and 28. The district boundaries follow approximately the natural divides between adjoining drainage basins. Since the whole north end of the county, except a narrow strip along Pine Island Bayou and the Neches River marshes, is drained into Taylors Bayou, and a vast area in the south half of the county is drained ultimately into the same bayou, all of this might be combined into one great

drainage district. However, a district of this size is not organized without considerable difficulty and delay; therefore the large basin has been divided into smaller units, each independent of the others except for the cooperation necessary to improve the main watercourse. It may possibly be expedient to form one large organization embracing the smaller districts just to enlarge Taylors Bayou.

All of the land drained into Hillebrant Bayou is formed into one district, No. 10. None of the areas drained by Bayou Din, Willow Marsh, and Pivitot Bayou may properly be treated as a separate unit, because each is dependent upon the lower end of Hillebrant Bayou for outlet and should share in the cost of cleaning and enlarging that bayou. All the land within the county limits that is drained by Taylors Bayou and the North Fork above their junction should have been included in district No. 11; but since a part of district No. 3, which already had been organized and had constructed ditches, is drained into the upper end of Taylors Bayou, and since a large area in Liberty County is drained into the North Fork by way of Pignut Gully, it is impracticable to form a perfect drainage unit in this instance. However, all of the land in that part of the county which is not included in district No. 3 is formed into a drainage district, and the main ditches are planned in the best possible way under the circumstances. Only part of district No. 20 can be drained into Taylors Bayou; the remainder must have an outlet eastward into Salt Bayou. Districts Nos. 25 and 28 have no outlets into existing watercourses; their drainage should be carried southward to the Intercoastal Canal.

PUMPING DISTRICTS.

That part of the county which can not be drained by gravity has been divided into convenient pumping units, and will be considered as districts Nos. 6, 7, 8, 9, 13, 14, 16, 17, 18, 19, 21, 22, 23, 24, 26, 27, 29, 30, 31, and 32. The marshes bordering on the Neches River were divided into such units that each would be entirely independent of all others, the bluff and the river front forming the complete boundaries of each.

District No. 8 is a small area between Beaumont and the Neches River, southeast of the city. About half of the district is high land and the remainder is river marsh. Because the Neches River is being shortened by several cut-offs at this point, it is deemed best not to present plans for drainage at this time. The newly graded Mansfield Ferry road across the marsh forms an excellent levee between this district and No. 9. Districts Nos. 13, 14, and 16 can be only partially drained by gravity; the south end of district No. 13 is very low and subject to frequent overflow. In order to insure

perfect drainage of this entire district, a levee must be built along Taylors and Hillebrant Bayous, and pumps installed at the mouth of Rodair Bayou. District No. 14 surrounds but does not include about 3,200 acres which a company proposes to drain independently. This tract might be included in district No. 14 without materially affecting the plans presented in this report. The south end of this district is very low and at times water will have to be pumped into Taylors Bayou, at the mouth of Alligator Bayou. It will not be necessary to construct levees to protect this area because the embankments of the Kansas City Southern Railroad and the Dallas and Sabine branch of the Texas & New Orleans Railroad will afford ample protection against backwater. The drainage from the whole of district No. 16 should be pumped into the ship canal at the mouth of Blacks Bayou. A levee must be constructed along the Neches River and the ship canal to protect the low land.

If found more convenient for the purpose of organization, district No. 9 may be divided into two districts of equal size, the canal connecting the Neches River with the McFaddin irrigation pumping plant at the narrowest part of the marsh being the dividing line. However, such a division would require the construction of an additional drainage pumping plant, with consequent increase in the cost per acre for the reclamation. It will be possible also to divide district No. 16 into two districts, the river marsh being one and the remainder of the land being the other. The bluff which forms the south boundary of the marsh becomes less marked as Sabine Lake is approached until it disappears entirely at a point about 1 mile from the lake. This would necessitate the construction of a levee from the end of the bluff to the lake and two pumping plants instead of one, thus increasing the cost of reclamation in each district.

South of Taylors Bayou the division of the land into pumping units is more or less arbitrary. At the present time there are no data at hand for determining whether one size of district on such land is more economical than another. In Louisiana there are districts of much greater size than the largest here recommended and others much smaller than the smallest here planned. Districts Nos. 18 and 19 may be combined into one district if more convenient, which would require changing the location of pumping plant of No. 18 and revising the ditch grades. Districts Nos. 21 and 24 can be combined or separated into smaller districts by rearranging the ditches and relocating the pumping plants. Districts Nos. 26 and 27, also, may be combined into one large district or separated into several smaller ones. Districts Nos. 29 and 30 may be divided into a number of smaller districts, but it would be impracticable to combine them into a large one on account of their shapes and relative location.

Although the Intercoastal Canal must be constructed before the reclamation of districts Nos. 24, 25, 26, 27, 28, 29, 30, and 32 can be carried out according to the plans presented herein, the cost of its construction is not charged to these districts. They are dependent upon the Intercoastal Canal for outlet, but since that waterway will be a benefit to the whole county as well as to adjoining counties and as it is possible that Federal appropriations will be made to help carry out this work no estimate is made of its cost. Should a different route be selected for the canal, the plans for the drainage of the above-named districts must be changed accordingly.

CITIES AND TOWNS.

The city of Beaumont is not included in any drainage district under the present arrangement. Some parts of the city will receive direct benefit when certain ditches of district No. 10 are constructed, but just what this benefit will be depends in part upon the location and construction of sewers. The greater part of Beaumont is drained into the Neches River and may be considered as a separate and independent drainage district. Port Arthur also is excluded from any of the enumerated drainage districts. It lies on very low ground and is affected by the same conditions as districts Nos. 16 and 17, but it has already built its own drainage system, including open ditches and pumping plant. The towns of Sabine and Sabine Pass and the half-mile strip of land connecting them, which have been filled in by suction dredges working in the Sabine Pass channel, are also excluded from any of the numbered districts.

DRAINAGE DITCHES.

CAPACITIES AND DIMENSIONS.

The first step in designing the drains for each district to be drained wholly or partly by gravity was to determine the area that will be drained by each ditch, including the areas drained by each main ditch at the points where laterals or submains will enter. For each pumping district only the whole area and the area drained by each main ditch was determined. The rate of run-off from each such area was computed by Frescoln's formula, as previously described, to find the required capacity of each ditch.

A profile along the route of each ditch was platted from the data on the map, and the grades of the ditch bottoms were determined from those profiles. The Chezy formula, $V = C\sqrt{RS}$, was used in computing the sizes of the ditches, C being determined by Kutter's formula with 0.030 as the value of the roughness coefficient n. All laterals in pumping districts were made of such size that they could be con-

structed by floating dipper dredges; the majority of them, therefore, will be much larger than necessary to carry the water that will reach them, and thus will provide large reservoir capacity. The minimum depth was fixed for all ditches at 6 feet, in order to provide (1) sufficient depth to float a dredge, (2) adequate outlet for tile drains and field ditches, and (3) better drainage along the ditches before the field drains have been constructed by the individual owners. The minimum bottom width of ditch for gravity districts was fixed at 2 feet, which is as narrow as it is practicable to make. With bottom width 2 feet, depth 6 feet, and side slopes 1 to 1, the top width of the minimum ditch will be 14 feet. The bottom widths for minimum ditches in the pumping districts are planned as follows: For the minimum depth of 6 feet, bottom width 12 feet; depths 6½ to 7 feet, bottom width 10 feet; depths 7½ to 8 feet, bottom width 8 feet; depths 8½ to 9 feet, bottom width 6 feet; depths 9½ to 10 feet, bottom width 4 feet. With side slopes 1 to 1, the top widths of such ditches will all be 23 to 24 feet. In the Appendix will be found a tabular statement of the sizes of the various ditches.

BERMS.

When constructing the ditches the waste material must be deposited far enough from the edge of the excavation so that the weight of the spoil banks will not cause caving of the sides of the ditch. For all minimum ditches there should be a clear berm of 6 feet between the toe of the spoil bank and the edge of the ditch; for ditches having bottom widths greater than the minimum but less than 8 feet, the berm should be 8 feet wide; and for ditches that have bottom widths of 8 feet or more, the berm should be 10 feet.

CLEARING RIGHT OF WAY.

A right of way must be cleared for the ditches located in timbered areas, and the width of such clearing depends on the width of the ditch. The total acreage to be cleared for each district is shown in the cost estimates, the area required for each ditch having been computed on the following basis:

Widths of right of way to be cleared.

Top width of ditch.	Width of clearing.	Top width of ditch.	Width of clearing.
Feet.	*Feet.*	*Feet.*	*Feet.*
Minimum to 20	60	41 to 46	140
21 to 26	80	47 to 53	160
27 to 33	100	54 to 60	180
34 to 40	120	61 to maximum.	200

LEVEES.

HEIGHT AND CROSS SECTION.

The height of the levees should be at least 1 to 2 feet above the highest water expected. The gagings at Beaumont by the War Department show a big rise in the Neches River after every heavy rain over its drainage basin. Following the heavy rains of December, 1911, the gage registered 5.12 feet above Gulf level, but as the first available record of this gage is for January 4, 1912, it probably does not show the extreme height of the December flood. In March, 1912, the gage registered 4.5 feet, and in May, 1912, 5.3 feet. Assuming that the high-water profile of the Neches is a straight line, beginning with the elevation 0.0 of mean low tide at the mouth of the river and passing through elevation 7.0 at Beaumont, the high-water mark at the mouth of Pine Island Bayou would be 9 feet; actual high-water marks at the Neches Canal Co. pumping plant on Pine Island Bayou have an elevation of 15.3 feet. This assumed high-water profile gives elevation of 8.5 feet at Colliers Ferry, 7.5 feet 1 mile above the Southern Pacific Railroad bridge at Beaumont, 6 feet at Mansfield Ferry, 3 feet at the Port Arthur Rice & Irrigation Co. pumping plant, and 2 feet at Port Neches. Since the general elevation of the marsh of district No. 6 is about 3 feet, the levee to protect it must be at least 13 feet high at the Neches Canal pumping plant and 6½ feet high at Colliers Ferry. The levee for district No. 7, whose elevation averages about 2 feet, must be at least 7½ feet high at Colliers Ferry and 6½ feet high 1 mile above the Southern Pacific Railroad bridge at Beaumont. The levee for district No. 9 must be at least 5 feet high at Mansfield Ferry and 1 foot high at the Port Arthur Rice & Irrigation Co. pumping plant, assuming that high tides have no effect above that point. Before construction is begun on the levees for districts Nos. 6, 7, and 9 further investigations should be made to determine the elevation of high water between Neches Canal Co. pumping plant and Port Neches.

The daily range of tide in the Gulf along Jefferson County is ordinarily 0.5 to 1.5 feet, but heavy winds blowing directly against the shore for considerable periods cause rises of several feet. Sometimes the storm tide affects only a small part of the coast line, sometimes it extends the whole width of the county. The highest tide in this locality was in 1900, when the water rose 16 feet at Galveston. The United States Coast and Geodetic Survey gages at Galveston show that from 1888 to 1890 there were 6 storm tides 2.7 feet or more above mean low tide, and from 1904 to 1909 there were 7 tides 2.5 feet or more above mean low tide. The highest of these were 4.9 feet in 1890 and 4.8 feet in 1909. In the streams and bayous several miles back from the coast the tides are neither so great nor so prolonged. To pro-

tect the districts in the southern part of the county against storms equal to those recorded at Galveston from 1888 to 1890 and from 1904 to 1909, all levees should be at least 4 feet high, which is in accord with the general practice in Louisiana, and those fronting directly on the Gulf should be at least 6 feet high. It is assumed that because such extraordinary storms as that of 1900 occur only at very long intervals, protection against loss by them will be by insurance rather than by levees of sufficient height to prevent overflow.

The proper cross sections of levees will depend upon the material used and the nature of the foundation. Where the material is dense and the foundation firm, as along the Neches River, the top width should be not less than 4 feet and the side slopes not steeper than 2 horizontal to 1 vertical. On the soft marshland in the southern part of the county the top width of levees should be not less than 6 feet and the side slopes not steeper than 3 horizontal to 1 vertical. The material excavated from the ditches designed for the latter territory will be much more than enough to build levees with the specified dimensions; therefore it will be possible to use many of the levees as roadways when they are properly settled and smoothed.

CONSTRUCTION.

In districts Nos. 6 and 7, which are covered with timber, all stumps, logs, and other vegetable matter should be removed from the base of the levees, which should then be plowed before any material is deposited. These precautions will insure a good bond between the old and the new material and prevent excessive seepage. In district No. 9 and others in the southern part of the county that are located on the open prairie where the ground is firm and above ordinary water level, a shallow ditch along the center line will insure a good bond. The berms for these levees should be at least 10 feet wide.

On the soft marsh lands levees must be constructed with great care, to prevent seepage and caving. They should be built in horizontal layers, each layer given some time to dry before the next is added; this will prevent yielding of the base as the material is deposited. The orange-peel bucket dredge is perhaps best adapted to this work because it can bring suitable material from below the soft surface mud, and by dropping the dirt from a considerable height can compact it in the levee. In order to prevent excessive pressure on the ditch banks which might cause sloughing of the soft earth, the berms in these marshes should be 15 to 20 feet wide. After the levee has dried sufficiently it should be smoothed and brought to grade. Usually prairie grass will soon cover the new levee and help keep it in shape. Careful grazing on the levees will give some protection against burrowing animals.

PUMPING PLANTS.

The design of pumping plants for drainage districts involves the study of many technical phases of their construction and operation, but experience seems to indicate that for the pumping districts herein recommended the centrifugal pump driven by steam power is the best type. Therefore the cost estimates of the plants are based upon this kind of equipment. Possibly electrical power or internal combustion engines may be found economical for some of the pumping plants.

After computing the maximum rate of run-off from each entire district by Frescoln's formula, a proper deduction was made for estimated storage in the ditches in order to determine the maximum rate at which the pumps would be required to handle the water. The pump sizes were computed by assuming the velocity through the pumps to be 12 feet per second. The engine sizes were determined by assuming that the water must be lifted 4 feet in all districts in the southern part of the county, 6 feet in district No. 9, 7 feet in district No. 7, and 8 feet in district No. 6. In times of excessive high water it might be necessary to lift the water to greater heights, but this contingency would be met by overloading or speeding up the engines.

BRIDGES, CULVERTS, AND FLUMES.

A complete plan of drainage must include provision for crossing highways, railroads, and irrigation canals, and the cost estimate must include the expense for the necessary bridges, culverts, and flumes. The sizes of openings and the types of structures recommended are indicated herewith.

HIGHWAY CROSSINGS.

Where drainage ditches with 2-foot bottom width are crossed by highways, culverts are recommended. Where such a ditch will have to carry only about one-fourth its computed capacity, a 36-inch corrugated iron pipe 35 feet long with a straight concrete head wall at each end will be suitable. Where the required capacity is about one-third the computed capacity, a similar culvert of 48-inch pipe is recommended. Where required capacities are approximately one-half, three-fourths, and the whole computed capacities, reinforced concrete box culverts with openings 4 by 4 feet, 5 by 5 feet, and 5 by 6 feet, respectively, should be provided. These box culverts should each be 20 feet long, with straight head walls. For ditches with 4-foot bottom width, similar culverts 5 by 8 feet with flaring wing walls are estimated.

Steel I-beam bridges with 20-foot width of roadway are recommended for crossing ditches with 6, 8, 10, and 12 foot bottom widths; the spans should be 13, 14, 16, and 20 feet, respectively. For crossing larger ditches, steel pony truss bridges of the Warren type, with 16-foot roadways, seem most suitable. The spans should exceed the

bottom widths of the ditches by 8 feet for 14 to 25 foot widths, by 9 feet for 30-foot widths, and by 10 feet for 35 to 50 foot widths. All bridges should be placed on concrete abutments.

RAILWAY CROSSINGS.

Culverts of 36-inch and 48-inch pipe are recommended where railways cross drainage ditches that will need to carry not more than about one-fourth or one-third, respectively, of the computed capacities of ditches with 2-foot bottom widths, as planned for highway crossings. All other railway crossings are estimated as half-through plate girder bridges on concrete abutments, with spans about equal to one-half the sum of the top and bottom widths of the drainage ditch.

IRRIGATION CANAL CROSSINGS.

As all irrigation canals consist of two levees between which the water flows over the natural ground surface, these must be carried over the drainage ditches at the crossings. It is impossible to determine the exact number of such crossings there will be, as many of the present irrigation canals may not be in use when the drainage ditches are constructed, and the data are not at hand to show where the proposed ditches cross all the irrigation laterals. The cost has been estimated for each crossing of a drainage ditch with a main irrigation canal in use at the time of the survey, and the total for each district has been included in the total cost estimates given on later pages. Culverts of 36-inch and 48-inch pipe should be used for the small ditches under the same conditions as explained for highway crossings. Where it is expected that the drainage ditch will carry one-half the computed capacity of the smallest ditch recommended, or more, the irrigation canal is to cross the drainage ditch in a wood flume supported on timber bents or piles. Each flume should be about 10 feet longer than the top width of the drainage ditch, thus allowing about 5 feet at each end for a firm bond with the bottom of the irrigation canal to prevent leakage.

PINE ISLAND BAYOU IMPROVEMENT.

All trees and brush should be cleared from the old channel of Pine Island Bayou for a strip 100 feet wide, which will give the present channel a capacity of 1,600 cubic feet per second, equivalent to about 0.6 inch run-off per 24 hours from the drainage area above the Jefferson-Liberty County line. From the county line to Voth, such a strip would contain 270 acres; clearing this would cost, at $40 per acre, $10,800. Divided along districts Nos. 1, 2, and 4 in proportion to their areas, this cost would amount to $1,605, $3,870, and $5,325, respectively, or 27.7 cents per acre.

TAYLORS BAYOU IMPROVEMENT.

The drainage areas and computed maximum run-off for Taylors Bayou at several points have been determined as follows:

Maximum run-off for Taylors Bayou.

Point of run-off.	Drainage area.	Total run-off.	
	Sq. miles.	*Inches.*	*Second-feet.*
At West Port Arthur railroad bridge	597	0.27	4,400
Just below Hillebrant Bayou	459	.35	4,400
Just above Hillebrant Bayou	312	.48	4,100
Just below North Fork of Taylors Bayou	280	.55	4,100
Just above North Fork of Taylors Bayou	120	.55	1,800
Just below Mayhaw Bayou	105	.63	1,800
Just above Mayhaw Bayou	30	1.10	1,000
At Hamshire railroad bridge	22	1.60	945

The total fall available in the 25 miles from the mouth of Mayhaw Bayou to West Port Arthur is only 4 feet. As indicated on the map, below Hillebrant Bayou there should be 5 cut-offs having a total length of 1.7 miles, and between this bayou and the North Fork of Taylors Bayou there should be 9 cut-offs aggregating 1.5 miles, with bottom width of 85 feet, depth 20 feet, and side slopes 1 to 1. The whole present channel of Taylors Bayou below the North Fork, except the cut-off bends, should be enlarged to the same dimensions. The fall below Hillebrant Bayou should be 0.16 foot per mile, and between that stream and the North Fork about 0.14 foot per mile. With these slopes the elevations of water surface above mean tide level will be 0.0 at West Port Arthur, 1.3 at Hillebrant Bayou, and 2.6 at the North Fork. Between the North Fork and Mayhaw Bayou the channel should be 50 feet in bottom width, 17 feet deep, with 1 to 1 side slopes and a fall of 0.14 foot per mile. The water surface at Mayhaw Bayou then would have the elevation 3.4. Between this point and the railroad bridge at Hamshire the available fall is 0.88 foot per mile, which will give ample capacity to a ditch of 25-foot bottom and 12-foot depth. The channel here recommended will prevent overflow at seasons of ordinary range of tide, which is small. However, on rare occasions severe storms will be accompanied by high winds that will raise the tides sufficient to obliterate the slight fall obtainable on the lower part of the bayou, and at such times short periods of overflow may be expected.

The excavation required by the improvement recommended is roughly estimated thus:

Excavation in Taylors Bayou.

Section.	Distance.	Excavation.
	Miles.	*Cubic yds.*
West Port Arthur to Hillebrant Bayou	8.0	2,025,000
Hillebrant Bayou to North Fork	9.7	2,119,000
North Fork to Mayhaw Bayou	6.0	469,000
Mayhaw Bayou to Hamshire	5.0	325,000
Total		4,938,000

The total cost of the four sections would be, at 6 cents per cubic yard below Mayhaw Bayou and 8 cents per yard for the upper section, $302,780. If the cost of each section is to be divided among the districts drained through that section in proportion to their areas, the total cost to each will be, according to the estimate: District No. 3, $61,175; No. 10, $36,450; No. 11, $151,174; No. 12, $15,639; No. 13, $4,860; No. 17, $1,215; No. 18, $9,112; No. 19, $5,637; and No. 20, $17,518.

The improvement of Taylors Bayou will necessitate building a bridge across the new channel at La Belle. This bridge is estimated to cost $7,100, which sum should be distributed among districts Nos. 3, 11, 12, and 20, in proportion to their areas. The amount to be charged to each would then be as follows: District No. 3, $910; No. 11, $4,770; No. 12, $710; and No. 20, $710. The cost of this bridge has been included with that of excavation for the Taylors Bayou improvement in the "Estimate of cost" rather than with the estimates for other bridges.

ESTIMATE OF COST.

The summarized estimate of total cost for each drainage district proposed for Jefferson County is given herewith, including the cost of operating each pumping plant. The acreages benefited do not include the areas covered by ditches and spoil banks.

Clearing right of way for all ditches located in the woods has been estimated at $50 per acre; this includes the cost of blasting all stumps 12 inches or more in diameter in the path of the dredge ditches and of grubbing all stumps, large and small, from the paths of the lateral ditches. The purchase cost of right of way 100 feet wide for the outlets for districts Nos. 20, 25, and 28, at $5 per acre, is included in the estimates. Excavation of ditches 8 feet or more in bottom width is estimated at 8 cents per cubic yard and smaller ditches at 10 cents, but the enlargement of Taylors Bayou below Mayhaw Bayou and on Hillebrant Bayou below Bayou Din is estimated at 6 cents per cubic yard. These prices are based upon average contract prices where payment is made in cash and not in bonds of the district which the contractor must accept at par and sell at a discount. The amounts of excavation were estimated by determining the average depth of cut, to the nearest half foot, from the profiles of the ditches. Where the material is to be placed in a levee, the price is increased 2 cents per yard to provide for putting all dirt on one side of the ditch and smoothing the embankment.

The cost of drainage pumping plants varies widely with the type of machinery, the character of foundation, and the expense of transportation to the site. The costs estimated for the plants in Jefferson County are average values from a large number of estimates made

by an eminent firm of contracting mechanical engineers for engines, pumps, and foundations, plus estimates for the buildings. It is possible that actual costs may vary considerably from those given. The annual costs of operation given include fuel, repairs, engineer's salary, and depreciation. A table prepared by the above-mentioned engineers showing comparative fuel costs of several different types of pumping plants was used in estimating the cost of fuel oil for each district.

The cost of legal, engineering, and incidental expenses was estimated at 10 per cent of the cost of construction.

COST BY DISTRICTS.

Drainage district No. 1:	
Clearing right of way, 158 acres in woods, at $50 per acre	$7,900
Excavation—	
65,500 cubic yards, at 8 cents per yard	5,240
129,900 cubic yards, at 10 cents per yard	12,990
Improving Pine Island Bayou	1,605
Bridges, etc., 1 railroad bridge, 60 feet	2,850
Engineering and legal expenses, 10 per cent	3,058
Total	33,643
Acres benefited in district, 5,790.	
Average cost per acre, $5.80.	
Drainage district No. 2:	
Clearing right of way, 146 acres in woods, at $50 per acre	7,300
Excavation—	
173,600 cubic yards, at 8 cents per yard	13,888
352,650 cubic yards, at 10 cents per yard	35,265
Improving Pine Island Bayou	3,870
Bridges, etc., 2 bridges, 8 culverts	5,650
Engineering and legal expenses, 10 per cent	6,597
Total	72,570
Acres benefited in district, 13,980.	
Average cost per acre, $5.20.	
Drainage district No. 3:	
(Plans by private engineers; construction work completed.)	
Drainage district No. 4:	
Clearing right of way, 190 acres in woods, at $50 per acre	9,500
Excavation—	
138,050 cubic yards, at 8 cents per yard	11,044
623,300 cubic yards, at 10 cents per yard	62,330
Improving Pine Island Bayou	5,325
Bridges, etc., 1 bridge, 14 culverts, 3 flumes	10,575
Engineering and legal expenses, 10 per cent	9,875
Total	108,652
Acres benefited in district, 19,200.	
Average cost per acre, $5.65.	

Drainage district No. 5:	
Clearing right of way, 108 acres in woods, at $50 per acre	$5,400
Excavation, 165,200 cubic yards, at 10 cents per yard	16,520
Bridges, etc., 19 culverts	6,475
Engineering and legal expenses, 10 per cent	2,840
Total	31,235
Acres benefited in district, 6,560.	
Average cost per acre, $4.75.	
Drainage district No. 6:	
Clearing right of way, 226 acres in woods, at $50 per acre	11,300
Excavation—	
98,700 cubic yards, at 8 cents per yard	7,896
456,100 cubic yards, at 10 cents per yard	45,610
Pumping plant, complete	34,000
Engineering and legal expenses, 10 per cent	9,881
Total	108,687
Acres benefited in district, 2,670.	
Average cost per acre, $40.70.	
Annual cost of operation: Total, $3,875; per acre, $1.45.	
Drainage district No. 7:	
Clearing right of way, 110 acres in woods, at $50 per acre	5,500
Excavation—	
67,500 cubic yards, at 8 cents per yard	5,400
193,000 cubic yards, at 10 cents per yard	19,300
Pumping plant, complete	38,500
Engineering and legal expenses, 10 per cent	6,870
Total	75,570
Acres benefited in district, 2,100.	
Average cost per acre, $36.	
Annual cost of operation: Total, $3,895; per acre, $1.85.	
Drainage district No. 8:	
(No plans prepared. See p. 15.)	
Drainage district No. 9:	
Excavation—	
136,900 cubic yards, at 8 cents per yard	10,952
688,600 cubic yards, at 10 cents per yard	68,860
Bridges, etc., 2 flumes	600
Pumping plant, complete	37,000
Engineering and legal expenses, 10 per cent	11,741
Total	129,153
Acres benefited in district, 6,440.	
Average cost per acre, $20.05.	
Annual cost of operation: Total, $4,960; per acre, $0.77.	
Drainage district No. 10:	
Clearing right of way, 748 acres in woods, at $50 per acre	37,400
Excavation—	
2,812,450 cubic yards, at 8 cents per yard	224,996
2,694,550 cubic yards, at 10 cents per yard	269,455
1,201,700 cubic yards, at 6 cents per yard	72,102
Bridges, etc.: 31 bridges, 103 culverts, 3 flumes	73,265
Taylors Bayou improvement	36,450
Engineering and legal expenses, 10 per cent	71,346
Total	785,014
Acres benefited in district, 90,110.	
Average cost per acre, $8.70.	

Drainage district No. 11:	
Clearing right of way, 697 acres in woods, at $50 per acre	$34,850
Excavation—	
5,142,500 cubic yards, at 8 cents per yard	411,400
3,111,750 cubic yards, at 10 cents per yard	311,175
Improving Taylors Bayou	155,944
Bridges, etc., 36 bridges, 77 culverts, 13 flumes	84,830
Engineering and legal expenses, 10 per cent	99,820
Total	1,098,019
Acres benefited in district, 95,820	
Average cost per acre, $11.45.	
Drainage district No. 12:	
Clearing right of way, 10 acres in woods, at $50 per acre	500
Excavation—	
46,350 cubic yards, at 8 cents per yard	3,708
455,700 cubic yards, at 10 cents per yard	45,570
Improving Taylors Bayou	16,349
Bridges, etc., 2 bridges, 8 culverts	3,925
Engineering and legal expenses, 10 per cent	7,005
Total	77,057
Acres benefited in district, 13,940.	
Average cost per acre, $5.55.	
Drainage district No. 13:	
Excavation—	
535,650 cubic yards, at 8 cents per yard	42,852
321,100 cubic yards, at 10 cents per yard	32,110
180,600 cubic yards, at 12 cents per yard	21,672
Improving Taylors Bayou	4,860
Bridges, etc., 3 bridges, 14 culverts	6,600
Pumping plant, complete	39,000
Engineering and legal expenses, 10 per cent	14,709
Total	161,803
Acres benefited in district, 12,490.	
Average cost per acre, $12.95.	
Annual cost of operation: Total, $5,640; per acre, $0.50.	
Drainage district No. 14:	
Excavation—	
1,140,100 cubic yards, at 8 cents per yard	91,208
723,100 cubic yards, at 10 cents per yard	72,310
Bridges, etc., 10 bridges, 35 culverts	22,625
Pumping plant, complete	46,000
Engineering and legal expenses, 10 per cent	23,214
Total	255,357
Acres benefited in district, 25,160.	
Average cost per acre, $10.15.	
Annual cost of operation: Total, $8,400; per acre, $0.33.	
Drainage district No. 15:	
Excavation, 103,750 cubic yards, at 10 cents per yard	10,375
Bridges, etc., 5 culverts, 1 flume	2,400
Engineering and legal expenses, 10 per cent	1,278
Total	14,053
Acres benefited in district, 2,850.	
Average cost per acre, $4.95.	

Drainage district No. 16:	
Excavation—	
323,100 cubic yards, at 8 cents per yard	$25,848
657,700 cubic yards, at 10 cents per yard	65,770
Bridges, etc., 4 culverts	750
Pumping plant, complete	45,000
Engineering and legal expenses, 10 per cent	13,737
Total	151,105
Acres benefited in district, 11,220.	
Average cost per acre, $13.45.	
Annual cost of operation: Total, $6,520; per acre, $0.58.	
Drainage district No. 17:	
Excavation—	
225,950 cubic yards, at 8 cents per yard	18,076
337,150 cubic yards, at 10 cents per yard	33,715
Taylors Bayou improvement	1,215
Pumping plant, complete	23,000
Engineering and legal expenses, 10 per cent	7,601
Total	83,607
Acres benefited in district, 3,620.	
Average cost per acre, $23.10.	
Annual cost of operation: Total, $3,745; per acre, $1.03.	
Drainage district No. 18:	
Excavation—	
1,017,500 cubic yards, at 8 cents per yard	81,400
428,950 cubic yards, at 10 cents per yard	42,895
Taylors Bayou improvement	9,112
Pumping plant, complete	39,500
Engineering and legal expenses, 10 per cent	17,291
Total	190,198
Acres benefited in district, 22,560.	
Average cost per acre, $8.45.	
Annual cost of operation: Total, $8,045; per acre, $0.36.	
Drainage district No. 19:	
Excavation—	
174,340 cubic yards, at 8 cents per yard	13,947
227,400 cubic yards, at 10 cents per yard	22,740
Improving Taylors Bayou	5,637
Pumping plant, complete	20,500
Engineering and legal expenses, 10 per cent	6,282
Total	69,106
Acres benefited in district, 4,530.	
Average cost per acre, $15.25.	
Annual cost of operation: Total, $3,950; per acre, $0.87.	
Drainage district No. 20:	
Excavation—	
60,900 cubic yards, at 8 cents per yard	4,872
1,455,750 cubic yards, at 10 cents per yard	145,575
99,200 cubic yards, at 12 cents per yard	11,904
Improving Taylors Bayou	18,228
Right of way for outlet, 92 acres, at $5 per acre	460
Engineering and legal expenses, 10 per cent	18,104
Total	199,143
Acres benefited in district, 15,400.	
Average cost per acre, $12.95.	

Drainage district No. 21:	
Excavation—	
976,700 cubic yards, at 8 cents per yard	$78,136
325,000 cubic yards, at 10 cents per yard	32,500
Pumping plant, complete	30,500
Engineering and legal expenses, 10 per cent	14,114
Total	155,250
Acres benefited in district, 16,820.	
Average cost per acre, $9.25.	
Annual cost of operation: Total, $6,430; per acre, $0.38.	
Drainage district No. 22:	
Excavation—	
523,200 cubic yards, at 8 cents per yard	41,856
577,400 cubic yards, at 10 cents per yard	57,740
Pumping plant, complete	24,000
Engineering and legal expenses, 10 per cent	12,360
Total	135,956
Acres benefited in district, 10,480.	
Average cost per acre, $12.95.	
Annual cost of operation: Total, $6,525; per acre, $0.62.	
Drainage district No. 23:	
Excavation—	
997,750 cubic yards, at 8 cents per yard	79,820
455,300 cubic yards, at 10 cents per yard	45,530
Bridges, etc., 2 bridges	1,600
Pumping plant, complete	28,500
Engineering and legal expenses, 10 per cent	15,545
Total	170,995
Acres benefited in district, 14,440.	
Average cost per acre, $11.85.	
Annual cost of operation: Total, $5,830; per acre, $0.40.	
Drainage district No. 24:	
Excavation—	
1,536,850 cubic yards, at 8 cents per yard	122,948
36,400 cubic yards, at 10 cents per yard	3,640
Pumping plant, complete	35,000
Engineering and legal expenses, 10 per cent	16,159
Total	177,747
Acres benefited in district, 19,590.	
Average cost per acre, $9.10.	
Annual cost of operation: Total, $7,250; per acre, $0.37.	
Drainage district No. 25:	
Excavation—	
59,400 cubic yards, at 8 cents per yard	4,752
1,484,250 cubic yards, at 10 cents per yard	148,425
33,600 cubic yards, at 12 cents per yard	4,032
Right of way for outlet, 36 acres, at $5 per acre	180
Engineering and legal expenses, 10 per cent	15,739
Total	173,128
Acres benefited in district, 10,970.	
Average cost per acre, $15.80.	

Drainage district No. 26:	
Excavation—	
935,700 cubic yards, at 8 cents per yard	$74,856
227,150 cubic yards, at 10 cents per yard	22,715
Pumping plant, complete	29,500
Engineering and legal expenses, 10 per cent	12,707
Total	139,778
Acres benefited in district, 15,830.	
Average cost per acre, $8.85.	
Annual cost of operation: Total, $6,125; per acre, $0.39.	
Drainage district No. 27:	
Excavation, 1,570,350 cubic yards, at 8 cents per yard	125,628
Pumping plant, complete	34,000
Engineering and legal expenses, 10 per cent	15,963
Total	175,591
Acres benefited in district, 19,490.	
Average cost per acre, $9.	
Annual cost of operation: Total, $7,105; per acre $0.36	
Drainage district No. 28:	
Excavation—	
2,275,450 cubic yards, at 10 cents per yard	227,545
6,000 cubic yards, at 12 cents per yard	720
Right of way for outlet, 26 acres, at $5 per acre	130
Engineering and legal expenses, 10 per cent	22,827
Total	251,222
Acres benefited in district, 14,160	
Average cost per acre, $17.75	
Drainage district No. 29:	
Excavation—	
1,329,300 cubic yards, at 8 cents per yard	106,344
338,500 cubic yards, at 10 cents per yard	33,850
Pumping plant, complete	35,000
Engineering and legal expenses, 10 per cent	17,519
Total	192,713
Acres benefited in district, 19,930.	
Average cost per acre, $9.65.	
Annual cost of operation: Total, $7,275; per acre, $0.36.	
Drainage district No. 30:	
Excavation—	
1,183,550 cubic yards, at 8 cents per yard	94,684
318,500 cubic yards, at 10 cents per yard	31,850
Pumping plant, complete	31,500
Engineering and legal expenses, 10 per cent	15,803
Total	173,837
Acres benefited in district, 17,100.	
Average cost per acre, $10.15.	
Annual cost of operation: Total, $6,535; per acre, $0.38.	

Drainage district No. 31:

Excavation—	
690,750 cubic yards, at 8 cents per yard	$55,260
564,200 cubic yards, at 10 cents per yard	56,420
Pumping plant, complete	26,000
Engineering and legal expenses, 10 per cent	13,768
Total	151,448

Acres benefited in district, 12,800.

Average cost per acre, $11.85.

Annual cost of operation: Total, $5,370; per acre, $0.42.

Drainage district No. 32:

Excavation—	
278,350 cubic yards, at 8 cents per yard	22,268
86,800 cubic yards, at 10 cents per yard	8,680
Pumping plant, complete	20,500
Engineering and legal expenses, 10 per cent	5,145
Total	56,593

Acres benefited in district, 4,620.

Average cost per acre, $12.25.

Annual cost of operation: Total, $3,420; per acre, $0.74.

SUMMARY OF AREAS AND COSTS.

No. of district.	Areas.				Length of ditches.	Cost.	
	Open prairie and marsh.	Timbered.	Total.	Benefited.		Total.	Average.
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Miles.*		*Per acre.*
1	850	5,100	5,950	5,790	16.9	$33,643	$5.80
2	10,720	3,620	14,340	13,980	43.4	72,570	5.20
3	46,760	.....	46,760	.....	.....	.....	.....
4	10,490	9,100	19,590	19,200	58.0	108,652	5.65
5	1,320	5,350	6,670	6,560	17.8	31,235	4.75
6	2,870	[1] 2,870	2,870	2,670	14.7	108,687	40.70
7	2,220	[1] 1,520	2,220	2,100	9.4	75,570	36.00
8	1,150	.....	1,150	.....	.....	.....	.....
9	6,720	.....	6,720	6,440	23.3	129,153	20.05
10	78,260	14,200	92,460	90,110	303.2	785,014	8.70
11	81,470	17,000	98,470	95,820	307.8	1,098,019	11.45
12	13,380	820	14,200	13,940	40.2	77,057	5.55
13	12,900	.....	12,900	12,490	47.7	161,803	12.95
14	25,770	.....	25,770	25,160	75.5	255,357	10.15
15	2,900	.....	2,900	2,850	8.7	14,053	4.95
16	11,650	.....	11,650	11,220	41.4	151,105	13.45
17	3,830	.....	3,830	3,620	17.3	83,607	23.10
18	23,060	.....	23,060	22,560	44.6	190,198	8.45
19	4,600	.....	4,600	4,530	14.6	69,106	15.25
20	15,890	.....	15,890	15,400	58.5	199,143	12.95
21	17,410	.....	17,410	16,820	43.2	155,250	9.25
22	10,880	.....	10,880	10,480	33.2	135,956	12.95
23	15,000	.....	15,000	14,440	46.3	170,995	11.85
24	20,230	.....	20,230	19,590	42.0	177,747	9.10
25	11,390	.....	11,390	10,970	44.4	173,128	15.80
26	16,320	.....	16,320	15,830	33.3	139,778	8.85
27	20,030	.....	20,030	19,490	40.2	175,591	9.00
28	14,600	.....	14,600	14,160	59.3	251,222	17.75
29	20,730	.....	20,730	19,930	54.1	192,713	9.65
30	17,660	.....	17,660	17,100	41.2	173,837	10.15
31	13,260	.....	13,260	12,800	37.9	151,448	11.85
32	4,800	.....	4,800	4,620	12.2	56,593	12.25
Outside of districts (includes water area)	.....	.....	17,590	.....	.....	.....	.....
Total	539,120	59,580	611,900	530,670	1,630.3	5,598,249	10.55

[1] Timbered marsh.

CONCLUSION.

SUFFICIENCY OF THE DRAINAGE PLAN.

The various improvements for each gravity district in Jefferson County have been planned to provide every part of such districts with sufficient outlet to insure against injury from excess of water except during and immediately following extraordinarily heavy storms. The ditches are so arranged that few points will be more than a quarter of a mile from a lateral. The design provides convenient and adequate outlets for tile drains or field ditches that landowners may wish to install.

In the pumping districts the ditches are planned 1 mile apart to serve the present needs of the county, and at a later date when the lands are put under thorough cultivation additional ditches will be needed to give complete drainage. The pumping plant for each district was designed to remove the excess water promptly after heavy rainstorms, to a depth of 4 feet below the ground surface at the site of the pumping plant, when the entire district has been thoroughly ditched, although canals 1 mile apart will not carry all this excess water promptly to the pumps and therefore the drainage will be much slower under the present plan than when the additional ditches and field laterals shall have been constructed.

VALUE OF DRAINAGE IN JEFFERSON COUNTY.

The money value of drainage is not easily measured, but the cost of this work is a permanent investment which must be added to the cost of the land if the proper returns are to be obtained from the first investment. As only 10 per cent of the area is timbered, the cost of clearing will be comparatively small. The worth of drainage may be measured by the increase in land values which it produces. If the land is as fertile in Jefferson County, Tex., as in some other localities along the Gulf coast, which can easily be determined, the net increase in crop values when the land has been reclaimed may be expected to yield very profitable returns upon the cost of purchase, drainage, and any other measures necessary to put the land into cultivation. Farming operations may be conducted more economically on drained than undrained land. Rice growing is the principal industry of the county, and this requires drainage as well as irrigation. Drainage is also insurance against loss of crops by excessive wetness. Localities where malaria exists will be benefited through the removal of stagnant pools that are the breeding places for mosquitoes which spread this disease. Drainage is also necessary if the good highway system, of which Jefferson County is proud, is to be economically maintained and extended.

APPENDIX.

DITCH SIZES AND EARTHWORK.

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 1:				
1 to 10, inclusive	*Feet.* 71,480	*Feet.* 2	*Feet.* 6 to 7	*Cu. yds.* 129,900
A	18,000	50	10 to 15	[1] 65,500
Total				195,400
District No. 2:				
1 to 5, inclusive	40,760	2	6	72,550
6	3,000	8	8	49,550
	2,800	12	7	
	2,700	4	6½ to 7	
	6,500	2	6½ to 7	
7 to 8, inclusive	7,600	2	6	13,550
9	3,500	4	6½	21,150
	5,700	2	6 to 7½	
10 to 13, inclusive	31,700	2	6 to 7	59,800
14	7,000	4	6½ to 7	29,350
	6,200	2	6	
15	7,000	4	6 to 7	29,850
	6,800	2	6	
16	3,500	4	6½	26,000
	9,500	2	6 to 6½	
17 to 22, inclusive	39,500	2	6 to 6½	72,150
A	15,400	30	8½ to 9	[2] 152,300
	5,600	25	8½ to 9	
	13,300	20	8½ to 9	
	7,900	18	7½ to 8	
	3,100	2	6½ to 7	
Total				526,250
District No. 3.[3]				
District No. 4:				
1	14,200	18	6 to 9	[4] 121,150
	12,200	2		
2 and 3	14,800	2	6 to 6½	27,500
4	5,600	4	6½ to 7	20,200
	3,000	2	6	
5	5,800	2	6	10,300
6	3,200	10	7½ to 8	33,700
	2,600	6	7½	
	3,800	2	6 to 6½	
7 and 8	14,400	2	6 to 7	28,000
9	5,280	8	9	69,100
	10,720	4	6 to 8½	
	5,000	2	6	
10	4,500	6	8 to 9	48,450
	5,500	4	6½ to 8	
	7,200	2	6	
11 and 12	15,300	2	6 to 6½	27,900
District No. 4—Continued.				
13	8,000	4	7½ to 8	54,350
	13,120	2	6 to 7	
14	12,000	4	7 to 7½	46,250
	5,800	2	6	
15	8,500	4	6 to 6½	31,300
	6,300	2	6	
16	9,500	4	6 to 6½	28,900
	3,700	2	6	
17 to 20, inclusive	16,200	2	6	28,850
21	2,200	6	8	[5] 31,150
	4,500	4	7 to 8	
	11,100	2	6 to 7½	
22	7,400	2	6	13,150
23	2,500	4	6	18,900
	7,500	2	6	
24 to 26, inclusive	29,700	2	5 to 10	56,900
27	6,000	4	6 to 8	35,200
	8,600	2	6	
28	5,500	4	6 to 10	30,100
	5,000	2	6	
Total				761,350
District No. 5:				
1 to 10, inclusive	70,700	2	6 to 8	[6] 118,900
11	8,600	4	6 to 6½	28,600
	4,600	2	6	
12 and 13	9,940	2	6	17,700
Total				165,200
District No. 6:				
1	6,200	10	6½ to 8	29,200
2	5,500	12	6 to 7	25,800
3	9,000	10	6½ to 8½	43,700
4	12,700	30	9 to 10½	243,500
	13,000	10	7 to 8	
5	31,500	10	8½ to 10½	212,600
Total				554,800
District No. 7:				
1	2,800	10	6½ to 7	11,500
2	6,500	12	6 to 7½	32,000
3 and 4	9,700	10	6½ to 7½	43,800
5	3,200	14	8½ to 9	104,500
	3,500	12	8½	
	8,600	10	7 to 8	
6	13,500	10	7 to 8½	[7] 68,700
Total				260,500
District No. 8.[3]				

[1] Willow Creek saves 458,700 cubic yards.
[2] Cotton Creek saves 292,400 cubic yards.
[3] Plans and estimates not made by Drainage Investigations.
[4] Trahan Gully saves 25,000 cubic yards.
[5] Bird Gully saves 14,800 cubic yards.
[6] Old Gully saves 3,550 cubic yards, ditch No. 1. No excavation stations 0 to 25, ditch No. 3.
[7] Brakes Bayou saves 9,150 cubic yards.

Ditch sizes and earthwork—Continued.

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 9:				
1 to 5 inclusive	*Feet.* 31,600	*Feet.* 10	*Feet.*	*Cu. yds.* 136,900
6	9,000	14	9	267,700
	12,000	12	8 to 8½	
	25,000	10	6½ to 7½	
7	10,000	34	9	420,900
	3,200	30	8½	
	19,300	20	7½ to 8	
	13,000	10	6½ to 7	
Total	.....	.....	.....	825,500
District No. 10:				
3	4,000	4	7 to 7½	24,800
	6,560	2	6 to 6½	
4	3,000	6	7	29,800
	4,000	4	6½ to 7	
	5,000	2	6	
5 to 7 inclusive	14,000	2	6	24,900
8	3,500	4	6½ to 7	18,200
	4,500	2	6	
9 to 13 inclusive	22,200	2	6	57,600
14	3,000	4	6	18,350
	6,600	2	6	
15	4,000	4	6 to 7	20,750
	5,600	2	6	
16	4,500	4	7 to 7½	25,755
	6,100	2	6 to 7	
17	5,500	4	6½ to 7½	28,450
	6,500	2	6 to 6½	
18	4,500	4	6½ to 7	30,150
	9,100	2	6 to 7½	
19	7,000	4	6 to 8	29,900
	7,400	2	6	
20	12,100	18	8 to 10	.....
	2,900	10	8	
	7,100	8	7 to 8½	
	900	4	7	
20	3,200	2	6	157,900
21	2,500	4	7	25,550
	9,900	2	6 to 7	
22	7,800	2	6	13,850
23	6,800	4	8 to 8½	37,400
	4,800	2	6 to 8	
24 to 32 inclusive	41,740	2	6 to 6½	74,250
33	8,000	4	.....	27,350
	5,400	2	6	
34 and 35	17,200	2	6 to 6½	30,600
36	8,000	4	.....	28,100
	4,800	2	6 to 6½	
37 to 39, inclusive	14,400	2	6	25,600
40	9,500	4	6 to 8	34,650
	5,100	2	6	
41	7,500	4	6 to 6½	28,700
	6,000	2	6	
42	5,500	4	6 to 7	24,000
	5,700	2	6	
43	2,000	4	7	14,950
	5,200	2	6	
44	3,000	4	7	16,950
	4,200	2	6	
45	3,000	4	6½ to 7	16,400
	4,800	2	6	
46	3,000	6	8 to 8½	35,800
	2,000	4	7½	
	8,200	2	6 to 7	
47	9,800	2	6 to 6½	17,950
48	4,000	4	6 to 6½	24,800
	8,600	2	6	
49	13,500	4	6 to 7	33,950
	1,500	2	6	
50	11,500	4	6½ to 7	40,850
	6,100	2	6	
51 and 52	13,000	2	6 to 6½	23,350

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 10—Continued.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*
53	3,500	4	6½	22,050
	7,100	2	6 to 6½	
54	2,800	4	8 to 8½	31,300
	10,400	2	6 to 7½	
55	8,000	2	6	14,200
56	2,500	4	.....	18,850
	7,500	2	6	
57	2,000	4	6 to 6½	18,900
	8,000	2	6	
58	5,500	4	6½ to 7	24,400
	6,500	2	6	
59	8,000	4	7 to 7½	30,750
	4,800	2	6	
60	9,000	4	7	35,050
	6,500	2	6	
61	2,400	6	7	39,400
	6,100	4	6½ to 7½	
	7,900	2	6	
62	4,000	2	6	7,100
63	6,500	4	6½ to 7	37,200
	9,500	2	6	
64	9,000	4	6 to 7½	34,450
	5,600	2	6	
65	6,000	4	6½	26,000
	6,800	2	6	
66 to 78, inclusive	68,580	2	6	121,850
79	7,500	4	6	18,500
	1,800	2	6	
80	10,000	4	6 to 6½	36,400
	6,800	2	6	
81	4,000	4	6	23,800
	6,400	2	6	
82 to 91, inclusive	56,100	2	6	99,650
92	3,000	4	6	19,950
	7,500	2	6	
93	4,000	4	6 to 6½	21,600
	6,800	2	6	
94	6,000	4	6	24,350
	5,200	2	6	
95 and 96	22,360	2	6	39,800
97	8,000	4	6 to 7½	39,150
	9,600	2	6	
98	11,000	4	7½	58,050
	11,200	2	6 to 7	
99	9,000	4	6½ to 7½	40,950
	7,400	2	6	
100	10,560	2	6	18,800
101	5,000	4	6 to 6½	22,650
	6,500	2	6	
102	4,500	4	6½	23,750
	7,500	2	6	
103	9,000	2	6 to 6½	16,550
104 to 122, inclusive	108,340	2	6	192,500
123	7,200	4	6 to 9	39,600
	8,800	2	6	
124 and 125	13,800	2	6	24,550
126	5,000	20	7½	117,600
	1,500	12	7½	
	7,900	10	7½ to 8½	
	3,300	8	6½ to 7	
	2,300	4	6½	
	7,000	2	6	
127	5,000	4	6½	19,400
	3,800	2	6	
128 to 137, inclusive	53,380	2	6 to 6½	96,800
138	2,000	4	7½	19,700
	7,500	2	6	
139	5,000	4	6½ to 7	19,150
	3,200	2	6	
140	4,600	2	6	8,200
141	3,500	4	6 to 6½	21,250
	7,300	2	6	
142	7,000	2	6	12,450

Ditch sizes and earthwork—Continued.

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 10—Continued.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*
143	1,400	4	6½ to 7½	15,350
	5,800	2	6 to 7½	
144 to 147, inclusive	26,780	2	6	47,600
148	6,500	4	6½ to 7	30,900
	7,500	2	6	
149	3,000	4	6	21,550
	8,400	2	6	
150	9,500	2	6	16,900
151	600	4	6	14,450
	7,400	2	6	
152 to 157, inclusive	31,800	2	6	56,500
Hillebrant Bayou below Pivitot B	39,000	50	19	[1]1,201,700
Main A	13,000	18	7½ to 9½	[2]237,250
	4,500	16	7½ to 8	
	13,000	12	7 to 9	
	3,500	10	7½ to 8	
	3,200	8	6 to 7	
	4,500	2	6	
Main B	12,000	70	12 to 14	[3]1,367,650
	5,500	80	10½ to 11½	
	11,500	70	10 to 10½	
	23,000	40	10 to 11	
	6,200	35	8½ to 9½	
	2,800	25	8½ to 9	
	4,000	20	9	
	6,700	16	9½	
	3,800	14	7½ to 8½	
	3,600	12	7	
	2,900	4	6	
	5,800	2	6	
Main C	6,000	30	9 to 10	[4]587,150
	11,000	35	9 to 9½	
	11,000	16	9½ to 12½	
	10,000	18	9½ to 10½	
	7,500	16	9 to 10	
	1,000	14	9	
	3,700	10	9	
	5,000	8	8½ to 9	
	5,800	6	6½ to 7½	
	1,600	2	6	
Main D	24,400	35	9½ to 13	[5]449,150
	2,600	20	9 to 9½	
	3,600	16	8 to 8½	
	5,500	10	8 to 8½	
	12,200	8	7½ to 8½	
	5,700	4	7 to 7½	
	6,300	2	6½	
Main E	16,800	6	8½ to 12	[6]102,000
	5,200	4	7 to 8½	
	1,500	2	6 to 7	
				6,708,700
District No. 11: 1 to 8, inclusive	47,900	2	6 to 6½	86,100
9	7,500	4	6 to 6½	31,450
	8,000	2	6	
10 to 12, inclusive	14,400	2	6	25,600
13	5,500	25	9 to 9½	170,200
	5,300	10	9 to 9½	
	3,600	8	9½ to 10	
	5,300	10	8 to 9	
	3,700	4	7½	
	3,300	2	6	

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 11—Continued.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*
14	5,000	4	6½ to 7	31,100
	10,000	2	6	
15 to 18, inclusive	26,500	2	6 to 6½	47,800
19	6,000	4	6 to 6½	24,650
	5,500	2		
20	15,000	4	6 to 9	58,700
	7,200	2	6	
21 to 23, inclusive	12,900	2	6	22,900
24	15,000	4	6½ to 7½	58,350
	7,000	2	6	
25	17,500	4	6 to 7½	61,050
	6,000	2	6	
26	14,500	4	6½ to 7	53,550
	8,000	2	6	
27	10,300	2	6 to 6½	19,600
28	5,000	4	to 6½	21,500
	5,000	2	to 6	
29 to 32, inclusive	16,500	2	6	29,300
33	5,000	4	7 to 7½	32,550
	8,000	2	6 to 7½	
34	9,000	4	6½	29,600
	3,000	2	6 to 6½	
35	5,000	4	6½	26,300
	7,000	2	6 to 6½	
36	7,500	4	6½	25,500
	3,060	2	6	
37	7,000	4	7 to 7½	33,350
	6,300	2	6	
38	3,500	4	6½	21,250
	7,000	2	6	
39	5,000	14	8½	106,550
	4,400	12	8	
	15,600	4	6 to 8	
40 and 41	13,000	2	6 to 7	24,500
42	8,500	4	6½ to 7½	33,800
	4,700	2	6	
43 and 44	10,800	2	6	19,150
45	14,000	4	6½ to 8	49,050
	4,000	2	6	
46	7,500	4	6 to 6½	25,250
	4,300	2	6	
47	16,000	4	7 to 7½	52,400
	2,000	2	6½	
48	6,300	2	6	11,200
49	2,200	14	8	48,100
	2,700	12	7½ to 8	
	2,700	6	7½	
	4,600	2	6	
50	4,000	4	8	29,200
	8,000	2	6 to 6½	
51	5,000	4	7	30,950
	8,500	2	6 to 6½	
52	5,000	2	6	8,900
53	3,200	4	7	26,650
	9,300	2	6 to 7	
54 to 57, inclusive	20,700	2	6 to 8	41,550
58	10,560	4	7 to 8	34,500
59 to 60, inclusive	10,600	2	6 to 7	20,200
61	16,700	4	6 to 7½	43,400
62	14,500	4	6½ to 8	52,950
	5,300	2	6	
63	15,000	6	7½ to 8	90,500
	4,000	4	7	
	8,400	2	6½	
64	2,700	2	6	4,800

[1] Including 8 cut-offs.
[2] Johns Gully saves 9,000 cubic yards.
[3] Hillebrant Bayou saves 395,300 cubic yards.
[4] Willow Marsh Channel saves 43, 650 cubic yards.
[5] Bayou Din saves 168,400 cubic yards.
[6] Pivitot Bayou saves 14,500 cubic yards.

Ditch sizes and earthwork—Continued.

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 11—Continued.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*
65	4,000	4	7	29,050
	9,000	2	6 to 6½	
66 and 67	17,800	2	6 to 7	32,400
68	6,500	14	10	93,600
	3,000	6	7½	
	5,500	4	7	
	4,500	2	6½	
69	9,000	14	7½ to 9	101,100
	6,000	8	6½ to 7½	
	2,500	6	6½	
	4,600	2	6 to 6½	
70	4,500	6	6	28,900
	9,500	2	6	
71	3,500	4	7	31,100
	10,900	2	6 to 6½	
72	11,000	2	6 to 8	24,050
73	6,000	8	7 to 7½	60,150
	3,000	6	7	
	4,500	4	6½	
	7,200	2	6 to 6½	
74	4,000	4	6½	13,650
	2,000	2	6	
75	8,000	6	7 to 8	51,500
	2,000	4	6½	
	9,800	2	6	
76	10,000	6	6½ to 7½	51,000
	9,800	2	6	
77	5,700	16	9 to 10	79,000
	13,800	2	6 to 9	
78	4,200	16	8½ to 9	60,100
	5,000	6	7 to 9	
	5,500	2	6	
79	3,500	4	6½	21,400
	7,060	2	6	
80 and 81	11,700	2	6 to 6½	21,350
82	2,500	4	7	24,350
	9,000	2	6 to 6½	
83	5,000	4	6½ to 7½	31,750
	9,700	2	6 to 6½	
84	4,000	4	7	31,250
	10,700	2	6 to 6½	
85	7,500	2	6	13,300
86	12,000	6	7 to 8½	79,500
	8,500	4	6½ to 7	
	6,700	2	6	
87	10,000	6	7 to 7½	60,950
	2,000	4	7	
	9,000	2	6 to 6½	
88	6,400	2	6	11,350
89	9,100	14	8 to 9	166,550
	8,100	12	8	
	3,800	10	8	
	3,200	8	7 to 7½	
	10,400	2	6 to 6½	
90	3,000	8	8 to 8½	85,600
	7,000	6	8	
	8,800	4	7½ to 8	
	5,700	2	6 to 7	
91	7,200	2	6 to 7	13,450
92	4,000	4	6½	19,550
	5,000	2	6 to 6½	
93	4,500	4	6 to 6½	19,250
	4,700	2	6	
94	4,400	2	6	7,800
95	10,000	6	8 to 8½	75,600
	6,500	4	6½ to 7½	
	7,700	2	6	
96	1,100	10	8	76,400
	12,900	6	6½ to 8	
	11,800	2	6 to 6½	

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 11—Continued.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*
97	6,500	4	7 to 7½	33,400
	7,700	2	6 to 6½	
98	10,500	6	8 to 9	119,850
	16,500	4	7 to 8½	
	9,800	2	6 to 7	
99 to 101, inclusive	16,600	2	6 to 6½	29,450
102	7,000	4	6½ to 7	28,550
	5,200	2	6	
103	5,000	2	6	8,900
104	6,500	4	6	22,400
	4,500	2		
105 to 109, inclusive	28,320	2	6 to 6½	51,450
110	3,500	6	8	59,300
	7,000	4	7 to 7½	
	11,700	2	6 to 7	
111	5,500	6	7½ to 8½	61,200
	4,000	4	7	
	13,400	2	6 to 7	
112	9,000	6	7 to 9	77,350
	6,000	4	6½ to 7	
	11,000	2	6 to 6½	
113 to 117, inclusive	25,000	2	6 to 6½	42,700
Main A	34,000	75	12½ to 13½	[1]3,458,400
	16,000	55	13½ to 15	
	16,500	50	12 to 14	
	26,000	45	10½ to 13	
	7,500	40	10	
	3,800	30	9 to 9½	
	16,200	25	8 to 9	
Main B	28,900	30	11 to 12½	[2]607,250
	18,600	25	8½ to 9	
	1,000	14	8	
	7,500	4	6 to 7½	
	4,500	2	6	
Main C	10,200	18	9 to 11	[3]194,950
	14,200	12	7 to 8½	
	6,600	8	7½ to 8	
	4,500	6	7½ to 8½	
	5,000	2	6 to 7	
Main D	21,500	25	9 to 11	[4]380,650
	3,500	20	8 to 8½	
	4,000	8	7½ to 8½	
	30,000	4	6 to 8	
Total				8,254,250
District No. 12:				
1	4,800	2	6	8,550
2	3,200	6	8 to 9	38,850
	3,000	4	7½ to 8½	
	7,600	2	6	
3 to 9, inclusive	33,900	2	6	60,300
10	7,000	4	6½	24,650
	3,560	2	6	
11 and 12	9,440	2	6	16,800
13	5,000	4	6½	25,950
	7,500	2	6	
14	4,000	6	7 to 8	35,500
	3,000	4	7 to 7½	
	6,500	2	6	
15 to 17, inclusive	20,000	2	6 to 7	37,600
18	1,900	6	7½	31,300
	12,300	2	6 to 7	
19 to 27, inclusive	49,980	2	6 to 6½	88,350

[1] Taylors Bayou saves 75,000 cubic yards excavation main A.
[2] Old ditch saves 148,000 cubic yards excavation main B.
[3] Old ditch saves 47,500 cubic yards excavation main C.
[4] Taylors Bayou saves 48,800 cubic yards excavation main D.

Ditch sizes and earthwork—Continued.

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 12—Continued.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*
Main A	6,000	10	0 to 10½	[1] 134,800
	10,900	6	9 to 10	
	8,600	4	6½ to 8½	
	4,000	2	6	
Total				502,050
District No. 13:				
1 to 10, inclusive	48,680	2	6	86,550
11	1,400	4	7½	16,350
	6,400	2	6 to 6½	
12 to 19, inclusive	46,000	2	6 to 6½	82,250
20	5,000	4	6 to 6½	24,200
	6,500	2		
21 to 25, inclusive	21,500	2	6	38,250
26	5,500	4	6½ to 7	32,050
	8,500	2	6 to 7	
27	8,000	4	6½ to 7½	33,250
	7,000	2	6	
28	12,500	16	9½	180,600
	5,500	14	7½ to 8	
	3,000	12	7	
	7,500	6	7 to 7½	
29	4,600	2	6	8,200
Main A	15,800	32	10 to 11	[2] 535,650
	6,700	25	8 to 9½	
	14,200	20	8 to 9	
	3,700	18	8	
	2,900	14	7½	
	3,200	8	7½	
	7,700	2	6 to 6½	
Total				1,037,350
District No. 14:				
1	5,000	10	8½ to 9½	70,850
	2,500	8	8	
	2,500	6	8	
	2,800	4	6½ to 7½	
	4,500	2	6	
2	6,400	2	6	11,350
3	5,000	6	7 to 7½	47,550
	2,500	4	7½ to 8½	
	8,900	2	6 to 9½	
4	5,500	6	7 to 7½	45,600
	6,500	4	6 to 7½	
	4,300	2	6	
5	1,500	7	7	31,550
	2,500	6	7	
	2,500	4	6½	
	6,500	2	6	
6	2,000	4	6½	20,550
	8,300	2	6	
7	7,500	4	6 to 7	27,250
	4,000	2	6	
8 to 21, inclusive	68,720	2	6	118,250
22	2,200	4	7	16,950
	6,000	2	6 to 6½	
23 to 25, inclusive	24,600	2	6 to 6½	44,450
26	2,500	4	7	25,600
	10,000	2	6 to 6½	
27	8,200	2	6 to 7	17,950
28	8,500	4	7	29,350
	3,500	2	6 to 6½	
29	9,000	12	7½ to 8	80,900
	2,500	8	7	
	2,500	6	7	
	3,000	4	6½	
	5,000	2	6	

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 14—Continued.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*
30	4,500	10	7	51,900
	3,500	7	6½	
	5,000	4	6	
	5,000	2	6	
31 and 32	14,200	2	6 to 7	30,250
Main A	25,000	45	10½ to 11½	[3] 681,000
	15,800	25	9 to 9½	
	3,600	10	8 to 8½	
	1,600	8	8	
	7,000	4	7	
	3,000	2	6	
Main B	2,500	40	10	185,050
	5,000	18	9 to 9½	
	12,000	12	8 to 8½	
	5,800	2	6 to 7½	
Main C	17,500	32	8½ to 9½	326,850
	4,500	16	8½ to 9	
	3,500	12	8½	
	5,000	8	7 to 7½	
	7,400	2	6 to 7½	
Total				1,863,200
District No. 15:				
1 to 7, inclusive	32,300	2	6 to 6½	57,900
Main A	4,100	6	8½ to 9½	45,850
	3,900	4	7½ to 8	
	5,500	2	6 to 8	
Total				103,750
District No. 16:				
1 to 5, inclusive	55,500	10	6½ to 8	253,350
6 to 10, inclusive	37,100	2	6 to 7½	72,400
11	4,700	10	7½	37,500
	7,100	2	6 to 7	
12	5,300	6	7 to 8½	29,900
	5,260	2	6	
13 and 14	21,100	2	6 to 7½	42,950
15	1,500	10	7	16,800
	5,500	2	6 to 6½	
16 and 17	11,100	2	6 to 6½	20,450
18	9,000	34	9	434,600
	6,000	24	8½	
	10,000	20	8 to 8½	
	22,500	10	6½ to 8	
Main A	4,500	12	9	72,850
	1,500	10	8½	
	4,500	6	8	
	6,300	2	6 to 7	
Total				980,800
District No. 17:				
1	20,900	28	8½ to 9½	313,150
	7,100	20	7½ to 8	
	8,500	10	6½ to 7	
2 to 6 inclusive	29,100	10	6½ to 8	135,200
7	8,800	12	6 to 7	38,000
8	11,000	8	7½ to 8½	52,750
9	6,000	12	6	24,000
Total				563,100
District No. 18:				
1	12,800	12	6	51,200
2	13,000	10	6½ to 8	57,850
3	15,000	12	8½ to 9½	187,500
	17,500	10	6½ to 8	

[1] Burrells Gully saves 8,300 cubic yards excavation main A.
[2] Rodair Bayou saves 10,700 yards excavation main A.
[3] Alligator Bayou saves 136,650 yards excavation main A.

Ditch sizes and earthwork—Continued.

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 18—Continued.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*
4	30,000	14	7½ to 9½	255,800
	10,000	10	7½ to 8	
	3,300	8	6½	
5	10,000	18	8½ to 9	259,600
	30,000	10	6½ to 8	
6	10,000	32	8	276,850
	10,000	25	7 to 7½	
	14,700	10	6½ to 7	
7 and 8	10,000	16	6	50,000
9 to 11, inclusive	15,000	14	6½	74,700
12	5,000	12	6½ to 7½	26,050
13	9,000	14	6 to 8	48,400
Main A	7,000	28	9½	158,500
	13,000	10	6½ to 9	
Total				1,446,450
District No. 19:				
1	4,400	10	6½ to 7½	20,300
2	4,000	12	6½ to 7	18,300
3 to 5, inclusive	23,000	10	6½ to 8	96,940
6	5,000	12	6½ to 7	22,500
7	4,100	10	6½	16,300
Main A	30,000	16	7½ to 9½	227,400
	6,500	8	6½ to 7	
Total				401,740
District No. 20:				
1 to 3, inclusive	20,000	2	6 to 7	37,800
4	9,000	6	7 to 7½	46,950
	3,000	4	6½	
	4,000	2	6	
5	6,000	4	6½ to 9½	32,300
	5,900	2	6	
6	10,000	4	6 to 7½	34,400
	3,800	2	6	
7	11,000	4	6 to 8	38,300
	3,700	2	6	
8 to 10, inclusive	19,400	2	6 to 8	41,150
11	2,000	4	6 to 7	21,600
	7,100	2	6 to 7½	
12	4,000	4	6½ to 7½	25,250
	6,800	2	6 to 7	
13	3,500	4	6 to 7	27,200
	8,500	2	6 to 7½	
14	5,000	4	6 to 6½	25,000
	7,000	2		
15	5,000	4	6½ to 7	28,600
	7,000	2		
16	6,000	4	6 to 6½	25,800
	6,000	2		
17	6,500	4	6½ to 7	32,850
	5,500	2	6 to 8	
18	11,500	4	8	68,550
	12,000	2	6 to 7½	
19	20,000	4	6 to 7½	59,300
	3,500	2	6	
Main A	8,700	12	8½ to 9½	94,100
	6,300	4	7½ to 8½	
	5,000	2	6 to 7	
Mains B and C	26,400	10	7½ to 9	151,900
Main D	40,000	35	10 to 10½	824,800
Total				1,615,850
District No. 21:				
1 to 4, inclusive	30,000	10	6½ to 8½	151,800
5 to 8, inclusive	26,460	12	6 to 7	121,000
9	3,960	10	6½	15,750
10	3,960	12	6	15,850
11 to 13, inclusive	15,000	10	6½	59,700
14	5,000	12	6½	24,900
15 to 18, inclusive	23,000	10	6½ to 7½	116,750
19	8,000	6	9 to 9½	43,750
20	35,400	12	6 to 8	171,500
Main A	20,000	20	7½ to 9½	208,200
	9,000	10	6½ to 7	
Main B	30,000	20	7½ to 10	372,500
	18,200	10	7	
Total				1,301,700
District No. 22:				
1 and 2	11,400	10	6½ to 7½	48,300
3 and 4	20,000	12	4 to 8½	96,350
5	6,200	10	6½ to 7½	31,950
6	3,500	12	7½	56,400
	8,700	10	6½ to 7	
7 and 8	17,700	12	4 to 8	82,700
9 and 10	8,100	10	6½ to 8	39,100
11	5,000	20	9½	350,600
	15,000	18	8½ to 9	
	15,000	14	7½ to 8	
	11,500	10	6½ to 7	
12	10,000	14	7½ to 8	96,800
	7,500	10	6½ to 7	
Main A	11,000	22	9½ to 10	298,400
	15,500	16	5 to 9	
	9,500	8	8	
Total				1,100,600
District No. 23:				
1	18,000	10	6½ to 8	85,100
2	35,000	25	7½ to 9½	378,800
	12,000	10	6½ to 7	
3	8,000	10	6½ to 8	37,250
4	20,000	14	7½ to 8½	216,100
	19,000	12	6 to 7	
5	10,000	16	7½ to 8	150,500
	10,000	14	6½ to 7	
	6,000	12	6	
6 to 9, inclusive	41,500	10	6½ to 8	190,400
10	7,800	12	6½ to 7	35,050
11 to 16, inclusive	24,000	10	6½	95,850
Main A	2,000	30	10	264,000
	10,600	18	9 to 10	
	20,400	10	8 to 9	
Total				1,453,050
District No. 24:				
1	5,000	18	9	136,300
	5,000	16	8	
	10,500	10	6½ to 7	
2	5,000	16	8½	164,550
	10,000	14	7½ to 8	
	8,500	12	7 to 9	
	5,500	10	6	
3	9,000	16	7½ to 8½	155,300
	6,000	14	6½ to 7	
	11,500	12	6	
4	10,000	14	7½ to 8	126,000
	14,000	10	6½ to 7	
5	10,000	14	7½ to 8	112,900
	11,500	10	6½ to 7	
6	5,000	16	7½	97,500
	10,000	14	6½ to 7	
	3,500	12	6	
7	13,000	16	6½ to 7	79,700
	3,000	12	6	
8 and 9	19,000	12	6 to 6½	36,400

Ditch sizes and earthwork—Continued.

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 24—Continued.	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*
Main A	5,700	50	10	615,700
	5,700	40	9½	
	5,700	35	9	
	5,700	30	8½	
	5,700	20	8	
	18,500	10	6½ to 7½	
Total				1,573,250
District No. 25:				
1	5,000	4	7½ to 8	38,400
	8,500	2	6 to 9	
2 to 22, inclusive	112,260	2	6	209,550
Main A	15,800	35	11	742,450
	21,000	28	13½	
	5,200	2	6½	
Main B	31,680	25	13	515,750
	8,440	18	12	
	5,220	2	10	
Main C	15,840	8	6½ to 7	71,000
	5,280	4	6	
Total				1,577,250
District No. 26:				
1	15,000	16	8½ to 9½	227,150
	5,000	14	7½	
	15,000	12	6 to 6½	
2	10,000	18	8½ to 9	188,400
	10,000	14	7½ to 8	
	3,000	12	7	
	7,000	10	6½ to 8	
3	10,000	18	8½ to 9	175,800
	8,000	14	7½ to 8	
	10,000	10	6½ to 7	
4	5,000	14	8½	154,800
	10,000	12	7½ to 8	
	11,000	10	6½ to 7	
5	15,500	10	5 to 7	58,150
6	7,500	16	7½ to 8	78,250
	6,000	10	6½ to 7	
Main A	5,500	36	10	280,300
	5,500	24	9½	
	5,500	16	9½	
	11,500	8	8½ to 9	
Total				1,162,850
District No. 27:				
1	11,500	30	9½ to 10	385,600
	7,500	25	10½ to 11	
	2,000	20	9½	
	1,000	18	9	
	1,000	16	8	
	2,500	14	7	
	14,900	12	6	
2	4,000	18	9	288,600
	2,000	16	10	
	10,000	14	10½ to 11½	
	3,500	12	9½ to 10	
	21,500	10	6½ to 9	
3	20,000	18	8½ to 9½	253,100
	5,000	14	7½	
	14,000	10	6½ to 7	
4	10,000	16	8½	216,100
	10,000	14	7½ to 8	
	16,800	10	6½ to 7	
5	10,000	16	8½	189,800
	10,000	14	7½ to 8	
	12,500	10	6½ to 7	
Main A	5,600	28	10	237,150
	5,600	22	9½	
	11,300	12	9	
Total				1,570,350

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 28:	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*
1 to 9 inclusive	54,060	2	6 to 7	100,000
10	5,000	4	6½	20,400
	4,400	2	6	
11	5,000	4	6½	24,950
	6,500	2	6 to 6½	
12	5,000	4	6½	24,100
	6,500	2	6	
13	5,000	4	6½	24,100
	6,500	2	6	
14	5,000	4	6½	24,100
	6,500	2	6	
15	5,000	4	6½	24,100
	6,500	2	6	
16	5,000	4	6½	24,100
	6,500	2	6	
17	5,000	4	6½	24,100
	6,500	2	6	
18	5,000	4	6½	24,100
	6,500	2	6	
19	5,000	4	6½	24,100
	6,500	2	6	
20	5,000	4	6½	24,100
	6,500	2	6	
21	5,000	4	7	26,550
	6,500	2	6 to 6½	
22	14,500	4	7 to 8	154,600
	39,000	2	6 to 6½	
Main A	40,440	50	14½	1,636,950
	16,560	20	13	
Main B	9,700	16	10	101,100
	2,700	4	6	
Total				2,281,450
District No. 29:				
1	12,000	10	6½ to 8½	55,700
2	11,500	12	6 to 8	52,300
3	5,500	16	7½ to 8½	70,300
	4,000	14	6½ to 7	
	2,300	12	6	
4	6,000	16	7½ to 8	70,300
	4,000	14	6½ to 7	
	2,000	12	6	
5	3,500	18	7½ to 9	77,900
	3,000	14	7½ to 8	
	5,700	10	6½ to 7	
6	4,000	18	9	81,100
	3,500	14	7½ to 8	
	5,100	10	6½ to 7	
7	4,000	18	8½ to 9	84,300
	2,000	16	7½ to 8	
	4,000	14	6½ to 7	
	3,000	10	6	
8	3,500	16	8½	75,900
	4,000	14	7½ to 8	
	5,500	10	6½ to 7	
9	3,000	16	8½	78,800
	3,500	14	7½ to 8	
	7,000	10	6½ to 7	
10	6,000	14	7½ to 8	73,400
	7,800	10	6½ to 7	
11	14,000	10	6½ to 8	65,400
12	10,000	14	6½ to 7½	72,500
	4,400	12	6	
13	66,500	12	2	266,000
Main A	5,700	20	10	243,000
	11,400	14	9 to 9½	
	5,700	12	9	
	5,700	8	8½	
	2,800	6	8½	
Main B	5,700	25	10	300,900
	11,400	18	9 to 9½	
	5,700	16	9	
	5,700	12	8½	
	5,700	8	8	
Total				1,667,800

Ditch sizes and earthwork—Continued.

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 30:				
1 to 3, inclusive	*Feet.* 24,100	*Feet.* 12	*Feet.* 6 to 9	*Cu. yds.* 110,400
4	4,500	18	8½ to 9	94,250
	3,500	16	7½ to 8	
	2,000	14	6½ to 7	
	4,500	12	6	
5	2,500	16	8½	78,800
	4,500	14	7½ to 8	
	6,500	10	6½ to 7	
6	14,500	12	5 to 6	49,550
7	1,000	20	5	46,750
	2,000	18	7	
	5,500	12	6	
8	2,500	16	7½ to 8	66,600
	2,500	14	6½ to 7	
	7,500	12	6	
9	5,500	16	6½ to 7	65,900
	7,000	12	6	
10	10,000	14	6½ to 7	63,600
	2,000	12	6	
11 and 12	29,700	12	6 to 7	124,400
Main A	7,400	50	10	623,700
	5,800	48	9½	
	14,500	42	6 to 9½	
	3,100	30	6 to 8½	
	5,700	25	8½	
	5,700	14	8	
	4,800	8	7½	
Main B	6,700	16	9½	194,100
	13,300	12	7½ to 9	
	9,000	10	6½	
Total				1,502,050

Ditch Nos.	Length.	Width of bottom.	Average cut.	Excavation.
District No. 31:	*Feet.*	*Feet.*	*Feet.*	*Cu. yds.*
1	5,000	16	8½ to 9½	97,050
	2,500	14	7½	
2	7,600	10	6½ to 7	63,650
	4,500	16	7½ to 8½	
	6,500	10	6½ to 7	
3	4,000	16	7½ to 8½	48,400
	6,000	10	6½ to 7	
4	9,300	10	6½ to 7½	40,900
5 to 11, inclusive	36,000	12	6 to 7	122,900
12	3,500	10	6½ to 7	14,550
13	1,000	16	8½	43,800
	3,000	14	7½ to 8	
	3,300	10	6½ to 7	
14	3,000	14	8½ to 9	6,400
	4,000	12	7½ to 8	
	4,200	10	6½ to 7	
15	15,000	16	8½ to 9½	227,150
	15,000	14	6½ to 7½	
	4,500	12	6	
Main A	6,000	32	10	493,100
	5,200	26	9½	
	5,300	22	8½	
	45,500	16	6½ to 8	
Total				1,254,950
District No. 32:				
1 to 4, inclusive	49,200	10	6½ to 9½	244,150
Main A	15,000	14	8 to 9½	121,000
Total				365,150

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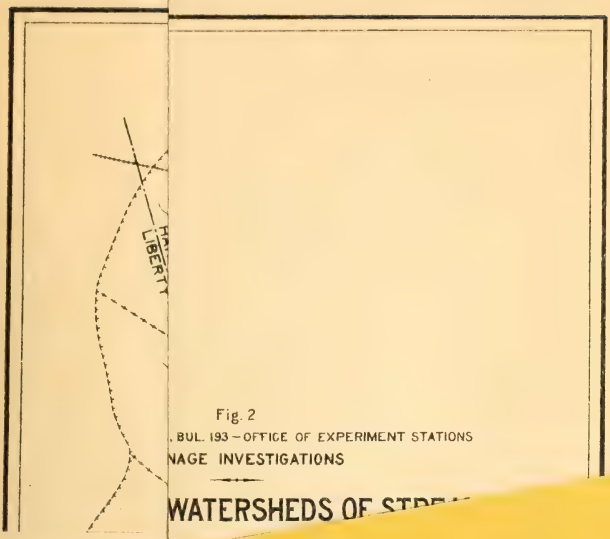

Fig. 2

. BUL. 193 – OFFICE OF EXPERIMENT STATIONS

NAGE INVESTIGATIONS

WATERSHEDS OF STRE

Fig. 2

U.S. DEPT. OF AGRICULTURE, BUL. 193 — OFFICE OF EXPERIMENT STATIONS

DRAINAGE INVESTIGATIONS

MAP SHOWING WATERSHEDS OF STREAMS AFFECTING THE DRAINAGE OF JEFFERSON CO. TEXAS

SCALE OF MILES

1 ½ 0 1 2 3 4 5 6 7 8

1914

E.T.C.

THE NORRIS PETERS CO., WASHINGTON, D. C.

Fig. 3

U. S. DEPT. OF AGRICULTURE BUL. 193 OFFICE OF EXPERIMENT STATIONS

DRAINAGE INVESTIGATIONS

S. H. McCRORY, CHIEF

MAP OF JEFFERSON COUNTY TEXAS

SHOWING TOPOGRAPHY AND
PROPOSED DIVISION OF THE COUNTY INTO

DRAINAGE DISTRICTS

WITH SYSTEMS OF DITCHES, CHANNEL IMPROVEMENTS AND LEVEES FOR EACH DISTRICT

PREPARED TO ACCOMPANY A REPORT AND ESTIMATES OF COSTS

BY

H. A. KIPP, DRAINAGE ENGINEER IN CHARGE OF PROJECT

ASSISTED BY A. G. HALL, DRAINAGE ENGINEER

1914

SCALE OF MILES

1 1/2 1 0 1 2 3 4 5

LEGEND

- Proposed Drainage District Boundaries
- Proposed Drainage District Numbers — 4
- Proposed Ditches
- Proposed Levees
- Proposed Channel Improvements
- Proposed Cut-offs for Old Channels
- Bench Marks — BM 15 BM 47
- Contours and Sea Level Elevations
- Bluffs
- Railroads and Stations — Voth
- County Highways
- Irrigation Canals
- Property Lines and Names — JNO. SMITH
- Present Bottom Elevations — 23 73
- Proposed Pumping Plants
- Timber Boundaries

HARDIN COUNTY

ORANGE COUNTY

LIBERTY COUNTY

CHAMBERS COUNTY

GULF OF MEXICO

SABINE LOUISIANA

SABINE PASS

JETTIES

BEAUMONT

PORT ARTHUR

Winnie

Stowell

Sea Breeze

High Island

Whites Ranch

Hamshire

Taylors Bayou

Pine Island Bayou

Pine Island Gully

Hillebrant Bayou

Hog Island Gully

Willow Slough

Doggy Creek

Pleasure Island

Keith Lake

Salt Lake

Lakes Kelly

Sabine-Neches Ship Canal

T. & N. O. R. R.

B. & S. F.

B. & O. R. R.

S. A. & A. P. R. R.

B. & G. R. R.

M. K. & T. R. R.

B. & S. & C. R. R. Co.

N. O. R. R. No. 1

P. A. R. & CO.

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Gulf Refining Co.

Spindletop

Viterbo

Voth

Westbrook

Westhaven

Elizabeth

Amelia

Walden

Griffing

Hebert

Fedeles

Mansfield Ferry

Collier's Ferry

Rosedale

Chester

Timberlane

Fairfield

Ellis Grove

Lucas

Townsend

Mc Faddin

Port Neches

Nederland

Groves

Port Acres

Tevis Park

Lakeview

Sunset Heights

Edgewood

Central Park

Pleasure Park

Lincoln Park

Lake Park

Lake Shore

Lake Vista

Lake Charles

Lake Arthur

Lake Sabine

Lake Charleston

Lake Calcasieu

Lake Mary

Lake Ellen

Lake Ethel

Lake Ida

Lake Ora

Lake Ola

Lake Ada

Lake Ina

Lake Ila

Lake Ila

Lake Ila